

Reading Augmented Paper: Children's experiences from a simulation study

David Frohlich, Ella Tallyn¹, Nadja Linketscher², Beat Signer³ Guy Adams Printing and Imaging Technologies Laboratory HP Laboratories Bristol HPL-2001-308 December 5th, 2001*

augmented paper, e-book, reading, pervasive computing The future of reading is often equated with the use of electronic books, which support the consumption of hypertext and hypermedia on a single screen-based device. In this study we report some early findings from the exploration of an alternative future, based on the simulation of *augmented paper* connecting printed content to screen-based resources. Six pairs of 10 year-old children were asked to find answers to questions about nature using a printed encyclopedia, a CD-ROM version of the encyclopedia, and an augmented paper booklet that linked the two resources. They also designed their own augmented pages by annotating a double page spread on seabirds. Although the CD-ROM was the most efficient medium for answering the questions, children thought the augmented paper booklet was more fun to use, and preferred it to the conventional book. Analysis of their behaviour, comments and designs revealed that augmented paper has the potential to radically increase the learning and comprehension of textbooks, through simple reading aloud facilities combined with multimedia explanations and demonstrations of concepts in the text.

^{*} Internal Accession Date Only

Approved for External Publication?

¹ Work Interaction and Technology Group, Kings College London, London, UK.

² User Centred Design Group, Orange, Bristol, UK.

³ Department of Computer Science, ETH Zurich, Switzerland

[©] Disappearing Computer Jamboree, 18-19th Oct 2001, Zurich, Switzerland

1. Background

Despite the ubiquity of computers, electronic documents and the World Wide Web, people continue to read and study from printed documents and books. In fact to be more accurate, in most workplaces, reading and writing on paper is now done *in combination* with reading and writing on screens (Luff, Hindmarsh & Heath 2000). Even as I type, I am experiencing the truth of this observation, since I am surrounded by papers strategically placed around my PC and will soon print out a draft of this introduction to proof read and amend on paper.

Some technologists argue that this hybrid phase of paper-and-screen reading will eventually be superseded by screen-based reading on better reading appliances (e.g. Harrison 2000, Schilit, Price, Golovchinsky, Tanaka & Marshall 1999). They point to the latest generation of e-books such as the Softbook from Softbook Press, as devices that support a more 'paper-like' reading experience and may eventually take over from conventional books. However, most social scientists who study the process of reading and writing are more cautious; pointing out the advantages and disadvantages of each medium for various actions such as searching, browsing, navigating, sharing and creating information (e.g. Sellen & Harper 2001, Luff, Heath & Greatbatch 1992).

While the goal of designing more effective reading appliances is a good one, it need not be pursued to the exclusion of other approaches that acknowledge the interplay of paper and screen-based resources. In this report we describe some early results from a 30-month European Union project to explore a new level of integrated paper-and-screen reading. The project, called Paper++, is developing a new form of augmented paper which allows the user to call up screen-based information by touching anywhere on its surface with a sensing wand (http://paperplusplus.net/).

Previous approaches to the design of augmented paper have chosen largely to tag whole documents, pages or specific areas of a page with optical marks or radio transponders (e.g. Arai, Aust & Hudson 1997, Heiner, Hudson & Tanaka 1999, Back, Cohen, Gold, Harrison & Minneman 2001, Johnson, Jellinek, Klotz, Rao & Card 1993, Masui & Siio 2000, Nelson, Ichimura, Pedersen & Adams 1999, Rekimoto & Ayatsuka 2001, Want, Fishkin, Gujar & Harrison 1999). Other methods track pointing or writing movements over the entire surface of a page by using a digitising underlay or document image processing from an overhead camera (e.g. Mackay & Pothier 2001, Robertson & Robinson 1999, Stifleman, Arons & Schmandt 2001, Wellner 1993). However, these methods are expensive, restrict mobility and require a document-tracking infrastructure. Our method builds on the active surface approach by using a 2D overlay pattern, printed in invisible conductive ink and sensed with a nibbed pen. In this respect it is most similar to the approach announced by Anoto, who are developing patterned paper for use with an optical pen sensor for handwriting capture (http://www.anoto.com/). In both cases the whole surface of the paper is made ready to accept manual pen-based input, although our emphasis is on capturing and relaying document, page and position information at low latency and cost. When relayed to a web database, this information can be used to fetch any arbitrary web content which has been previously associated with a specified region of the current page.

The use of this kind of surface-augmented paper establishes a more intimate connection between paper and electronic materials. This in turn opens up a large design space for multimedia publishing and consumption. The Paper++ project is exploring this design space within the educational domain, through a combination of naturalistic studies of reading and writing, interviews with publishers and teaching professionals, conceptual design work, prototyping, simulations and evaluations. This report describes the findings of our first simulation study, in which we contrast the reading behaviours of 10 year-old children on paper, screen and augmented paper. The main aim of the study was to understand the relative strengths and weaknesses of each medium for reading, learning and enjoyment, and the prospects of augmented paper for enhancing the paper reading experience.

2. Methods

2.1 Experimental materials and design

Given our basic interests in understanding the properties of paper, screen and augmented paper in an educational reading activity, we set about searching for a core educational textbook that was also published in web or CD-ROM format. This would allow us to present children with separate but similar paper and screen-based materials, and also to compose an augmented section of the book from their overlap on the same topic. We eventually selected the *Encyclopedia of Nature* from Dorling Kindersley, since this is published in attractive book and CD-ROM formats, both of which are readily accessible in leading bookshops and are commonly found as teaching resources in primary school classrooms in the UK. Furthermore, Dorling Kindersley (now part of the Pearson Group) were quick to grant permission to use these materials in the study, and also agreed to become a longer-term partner in the research by participating in future content-provider interviews.

An augmented paper booklet was created out of a subsection of the printed encyclopedia. We chose a six-page section on prehistoric life stretching from pages 12 to 17 of the book. Since these pages are viewed two at a time as double-page spreads when the book is opened, the booklet was printed on 4 double-sided A4 sheets with additional cover and back pages added to the 6 internal pages (see Appendix A). Because the core Paper++ technology was not mature enough to use in this study, we chose to simulate it by using multiple UPC 6-digit barcodes on each page (see again Appendix A). Each barcode indexed an associated piece of information stored on a remote web server and displayed in a web browser. Further details of this implementation are given in the next section. Associated items were taken from the Prehistoric life part of the CD-ROM, represented as a giant fossil on the home screen.

A variety of associations were chosen to reflect a diversity of possible data types such as audio, video, graphic animation, text and images. These data types were also used to cover diversity of semantic links such as definitions of terms, expansions of the text, examples, and explanations. The reader can view associations from an on-line Paper++ emulator at the following website:

http://gordon.inf.ethz.ch/dinosaurs/static/search.htm The input codes for some typical associations are as follows: A textual definition of DNA (ID 1, Page 01, x 30, y 230) A video of a volcano erupting (ID 1, Page 01, x 150, y 50) A graphic animation of the evolution of the horse (ID 1, Page 03, x 100, y 220) An auditory explanation of the Jurassic period (ID 1, Page 05, x 152, y 68) An extra box on Reptiles with spoken text and graphics (ID 1, Page 06, x 38, y 45)

Given this booklet, and the original book and CD-ROM, we designed a repeated measures experiment in which pairs of children began with either one of the original resources and transferred to the augmented booklet. This allowed us to collect a modest amount of control data on how children interact with conventional printed and electronic materials, but a maximum amount of experimental data on their interaction with the augmented paper booklet. It also allowed the children themselves to make direct comparisons between at least one conventional medium and the augmented paper medium, when used for the same kind of task. In addition, pilot work suggested that children themselves were capable of expressing augmented booklet design preferences by annotating pages of the printed book. We asked them to do this on a double-page spread on seabirds (pages 212 and 213 in the book) at the end of the experiment. The seabird pages are shown in Appendix B while a summary of the experimental design is shown in Table 1 below.

SUBJECTS	SESSION 1	SESSION 2	SESSION 3
Pair 1	Paper book	Augmented booklet	Re-design booklet
Pair 2	CD-ROM section	Augmented booklet	Re-design booklet
Pair 3	Paper book	Augmented booklet	Re-design booklet
Pair 4	CD-ROM section	Augmented booklet	Re-design booklet
Pair 5	Paper book	Augmented booklet	Re-design booklet
Pair 6	CD-ROM section	Augmented booklet	Re-design booklet

Table 1. Experimental design.

2.2 Equipment and system architecture

We used an HP laptop running Windows 2000 as the presentation device for the CD-ROM material and the augmented paper associations. To trigger the associations, the laptop was equipped with a standard Agilent barcode reader wand (HBSW-8300). This plugged into the RS232 serial port at the rear of the laptop and could be stretched about 150 centimeters from the port on a coiled wire.

The Paper++ server framework was developed and implemented by ETH Zurich. It consists of three main components as shown in Figure 1: a barcode decoder and visualization component, the XIMA server component supporting database access from various types of client devices, and the interaction and application model implemented using the OMS Java data management system.



Figure 1. Server framework for the augmented paper simulation.

In a typical user session, the wand transmits recognized barcode information in a preprocessed ASCII format to the client device, which then decodes relevant information such as the unique document ID, the page number and the x- and y-position form the barcode. In the next step, an HTTP request including this information about the physical location on the paper document is sent to the XIMA server component. Based on the interaction model and its transformation data, the server retrieves the appropriate information from the application database and returns the result in the desired output format (Signer, Grossniklaus & Norrie 2001). The format of output is dependent on the digital presentation device. For this experiment it was rendered in HTML format in a web browser window on the laptop screen. However, the output format can be modified to suit a variety of devices including a WAP-enabled phone or a normal voice telephone. The output is sent back to the digital presentation device as an HTTP response and then visualized on that device.

2.3 Subjects

The project is committed to researching the learning activities of children, students and members of the public in three distinct phases. In this phase we chose to examine the learning behaviours of young children at the top end of primary school who tend to be taught all subjects by a single teacher. The children in this study were 9 or 10 years old and about to begin year 5 of primary school (Key Stage 2). In addition, we decided to recruit pairs of children to come into the Labs together. This was partly to recreate classroom conditions in which children are often asked to work together in pairs, especially around a computer. It also allowed us to study the collaborative activities involved in social reading, and to gain further insight into each individual's cognitive activities through the talk and actions they direct to each other. Six pairs of children were recruited during the summer holidays of 2001 through responses to an email request sent out to the HP Labs Bristol site. They tended to be the children of individual staff members, who came into the labs with a friend.

2.4 Tasks

Since the aim of the experiment was to examine the effect of different presentation media on reading, learning and enjoyment, we attempted to design tasks that were both educational and yet potentially fun to perform. The tasks were expressed as a series of questions children had to answer in each of the first two sessions. Questions were chosen to reflect three different kinds of reading adapted from taxonomy of reading types (Adler, Gujar, Harrison, O'Hara & Sellen 1998): Q1. Searching for a fact

- Q2. Comparing between alternatives
- Q3. Browsing for interesting items

Instantiations of these kinds of questions were formed for the augmented paper booklet and also for a separate section of the book and CD-ROM on *Birds*. These questions were presented to the children on the question sheet shown in Appendix C. The answers to questions 1 and 2 in each session were written on this sheet. Since question 3 involved generating a quiz for parents to answer later, the children were given separate blank question and answer sheets to write on for this.

In Session 3, we invited children to design their own augmented book pages. This was done by sticking the double-page spread on Seabirds shown in Appendix B onto a flipchart, and giving children pens and stickers with which to annotate it. Children were asked to draw around regions of the printed pages to indicate active areas that might be 'scanned' for extra information. They were also asked to draw lines out from these areas to the border of the flipchart where they could describe the extra information in words, and attach stickers corresponding to different kinds of data. We made 4 types of stickers available: Silent Video (V), Sound (S), Picture (P) and Text (T). These could be used multiple times in any combination.

2.5 Procedure

The experiment was carried out in a usability lab within HP Labs Bristol. An indication of the arrangement of children, equipment and materials in the room is shown in Figures 2, 3 and 4. These images were taken from video recordings of the experiment, and include up to three camera views mixed into the same frame. Pairs of children worked in the lab for about two hours, comprising three half hour 'sessions' as shown in Table 1, with half an hour's rest. Typically the children were keen to try the augmented booklet immediately after their initial session on the printed book or CD-ROM, and therefore took a break before the final design session. In each session, children were given about 20 minutes unassisted time to work through the question sheet or perform the design exercise. The last 10 minutes of each session were spent interviewing the children about their answers, annotations and experiences (see Appendix D).



Figure 2. Arrangement of materials in the paper book condition



Figure 3. Arrangement of materials in the CD-ROM condition



Figure 4. Arrangement of materials in the augmented paper booklet condition

3. Results

3.1 Overall preferences and performance

After Session 2, we asked the children which medium they preferred for answering the questions on nature. Their responses are summarised in Table 2. This shows that preferences depended on whether they used the paper book or the CD-ROM in Session 1. If they used the printed encyclopedia first then they tended to prefer the augmented booklet. If they used the CD-ROM first, they tended to prefer the CD-ROM to the augmented booklet. When asked to include the missing third medium in their ranking, the children always ranked the printed book third below the other two media which fought with each other for first place in the children's minds. There

seemed to be some agreement that although the CD was probably the most efficient medium for answering the questions, the augmented booklet was more fun to use These responses reflected a general attraction towards multimedia materials for learning and a heightened sense of expectation around the 'hidden' information contained behind the barcodes on the booklet.

PAIR	SESSION ORDER	PREFERENCES
1	Book - Booklet	Book, Booklet
2	CD – booklet	CD, CD
3	Book - Booklet	Booklet, Booklet
4	CD – booklet	CD, CD
5	Book - Booklet	Booklet, Booklet
6	CD – Booklet	Booklet, CD

Table 2. Summary of media preferences

There was little difference in the accuracy of answers to questions across media. All pairs managed to answer the factual questions correctly within the given time. The groups differed only in the number of quiz questions they generated towards the end of Sessions 1 and 2. An average of 5 questions (and answers) were generated when working with the CD-ROM, whereas an average of 3 questions were generated when working with the book or the augmented booklet. Insofar as this reflects efficiency on the task, then the CD-ROM can be said to be a slightly more efficient medium for learning than the other two media.

3.2 Experiences with the printed book

3.2.1 Behaviour

Using the video recordings from each experimental session, we analysed the behaviour of children when completing the tasks. This involved making a detailed index of activities, identifying routine procedures or recurrent problems, and making collections of various interactional phenomena for closer examination. In this section we draw on this analysis to summarize some of the most obvious properties of the children's interaction with the printed book. Similar summaries are presented for the CD-ROM and augmented booklet media in later sections.

• Wide range of actions (tactile and flexible properties of the book)

The children exhibited a wide variety of physical actions when using the reference book. These behaviours were afforded by the physical dimensions and structure of the book as well as the material qualities of the paper. Behaviours were also shaped by the perceived value of the book and social models of use e.g. books are mobile objects that can be borrowed and touched. Table 1 lists a range of activities performed on the book.

• Equal access to information

Although the book is large and heavy, its discreet and robust nature allowed the children to move it by dragging and pushing it around on the desk. This made it easy and quick for the children to re-configure their workspace, and so children tended to swap activities frequently, sharing the tasks equally. They usually began with the book placed between them, where both children could easily

access it. When the tasks change or the children swap roles in an activity the book is often moved to accommodate the shift in activities, for example it might be pushed towards the back of the table to make room for writing activities. In order for one child to get a better view the book can be temporarily moved or tilted. For example Lydia in Pair 5 is reading an item and struggles to understand a word or sentence, so she tilts the book towards herself and Iann to give them both a better view then lays it back down on the desk when she has finished (see Figure 5). In another instance Lydia moves the book to help her draw Iann back into an activity. She can view the book and is struggling to adapt a sentence from the book into a question. Iann has sat back and does not appear to be involved in the activity at this point. Lydia explains her problem to Iann, and at the same time drags the book to the nearside of the table. She turns to face him as she finished explaining. Iann now has better access to the book, and within seconds is back at the book and focussed on the area she is looking at.

Book activities			
Finding the information			
 Linear searching- turning pages page by page 			
 Skipping - turning several or a large chunk of pages 			
 Scanning- flicking rapidly through a block of pages 			
• Comparing - moving back and forth between different pages, held open.			
 Comparing - bending pages to look items on different pages 			
• Collaborative searching – sharing page turning, directing/controlling			
another's page turning			
• Book-marking – inserting fingers and hands between pages to mark places			
they want to go to, or places they have been			
Viewing the information/performing tasks			
 Identify an item or area of a page for another - point at paper, tapping 			
paper pen on paper			
 Flattening the centre fold of the pages with wrist or hand. Or flattening 			
single page with hand – fingers spread.			
 Tying reading/looking activity to the text - tracing words with fingers or 			
pen as they are being read			
• Marking an item or area of page for self or another – finger held on page			
whilst words are being copied, framing page with arm, framing section of			
page with fingers			
• Performing distinct and separate activities - separate activities using the			
same page, and separate activities on different pages			
Accessing the book/changing the nature of the task/or division on labour			
• Repositioning the book to gain a better view either themselves or for the			
other - dragging, pushing or tilting the book			
• Reorganizing the workspace to make room for other activities - pushing or			
pulling the book on the desk.			

Table 3. Actions performed on the book



Figure 5. Re-positioning the book during reading.

• Collaborative properties (including parallel activities)

Children often search for the same item together. Both children become involved in turning the pages. Children often literally turn pages together as shown in Figure 6. Sometimes one child begins a search, and the other will join in or take over.



Figure 6. Turning pages together

Because of the wide range of information displayed at one time on the pages, and the easy access to the pages their attention can wander separately, and focus on separate items, allowing them to do separate tasks in parallel. This could be navigation or reading. For example one child can navigate to an item while the other reads something on another page (see Figure 7: Lydia reads from one page, whilst Iann browses through other pages).



Figure 7. Parallel use of book

The books pages are designed to be touched, unlike a computer screen which children are often told not to touch. The horizontal orientation of the book (flat on the table) together with the tactile nature of the pages makes this easy. Pointing and holding finger on the page to mark an item was a common activity. Most often pointing was used to identify an item of interest for the other child, and possibly to mark it for themselves. Once an item of interest is identified the children tend to keep their fingers next to an item as they examine and discuss it. Furthermore one child will often mark a word or fact for the other child to reference while they copy it onto their answer sheet or use it to construct a question. For example Iann and Lydia were using the book to find the weight of a puffin. They have moved to the right page using the index, and are looking for the puffin. Lydia spots the puffin, and points it out to Iann. Iann then spots the weight of the puffin and marks the information with his finger. They both examine the information together keeping their fingers on the page. Iann then moves to write the answer down and Lydia holds her finger next to the information while he copies it down (see Figure 7).



Figure 7. Using a finger as a placeholder.

• Use of a wider range of information

In books all the information is presented on one level. All information exists on the level of a page and there is no hierarchical structure to the *access* of information. Instead information is organized by position in the book and on the page. This allowed the children equal access to all the information including information that was unrelated to the task at hand. The children sometimes used previously unrelated information to help them achieve their tasks. E.g. when writing the false answers for their multiple choice questions the children would spot facts related to other animals and use these to create convincing alternatives to fool their parents.

3.2.2 Comments

Interviewing children about their experiences with the printed book was hard work. The familiarity of printed textbooks made them the least 'noteworthy' medium in children's minds. Their overall attitude was that 'its just a book'. This was despite, or perhaps because of, being extremely skilled in the handling and use of the book as a resource for answering questions (see above). However, when pressed for comments on the design of this particular book, three responses emerged.

• More indexing

Some pairs of children said there could have been better indexing of material in the encylopedia, through an improved contents list or index. This comment usually emerged when discussing the difficulty of finding information on the weight of a Puffin or on which birds eat insects (Bird questions 1 and 2 in Appendix C). Although Puffin was in the index, it was too specific a term to appear in the contents list where children tended to look first. Insects were easy to find in the contents and index, but not in conjunction with bird diet. The children were frustrated by this, and tended to recommend a quick fix where the items in question were simply added to the contents list. In practice, they reported using the contents list more approximately to chose a place from which to start browsing:

L: Instead of looking through the pages we looked in the contents... and he said pigeons (Lydia, Pair 5).

• More content

Several children complained that there was not enough detailed information on individual birds and their diet. Such information was restricted to a breakout box on one bird within each double-page section. Others requested a greater use of space in the layout of existing text and graphics, since these tend to be packed quite densely on a page. The fact that these changes might result in a bigger book did not seem to deter children in the slightest, as shown in the following dialogue:

M: I think it could be a little more spaced out

I: But that would make it bigger. Do you mind if it's bigger?

M: Shakes head.

I: What if it was twice as thick?

M: *I* don't mind 'cos I've got one at home that's twice as thick (Maxine, Pair 3)

• Re-organisation of content for the task at hand

Some of the layout conventions used in the book were too subtle for the children to notice at first. This applied to the breakout boxes of bird details, which were always positioned at the top right of each double-page, and even to the use of double-pages to represent a bird category. Consequently some pairs recommended more obvious methods of organisation that may have worked better for the task at hand, such as finding Puffins or other birds by name in an alphabetic sequence:

A: It would be good if they could put all the animals in alphabetic order (Alex, Pair 1).

3.3 Experiences with the CD

3.3.1 Behaviour

The children using the CD did not display such a rich set of physical interactions as when using the book. This was largely because of the limited physical access to the digital information. However this did seem to initiate more discussion between the children as to how tasks were approached. In this session the children discussed actions that seemed to be achieved without explicit discussion when using the book. For example, a child with the mouse might explain to the other child what they intend to do next, and the other child may respond to this with other ideas about this course of action.

• Multiple window navigation

The children's success in navigating the content on the CD depended partly on their understanding of the various interface conventions used in the design of the CD. Children that had previous experience of similar interfaces navigated more easily than those that did not. One particular convention that caused problems was the use of multiple overlapping windows for presenting successively more detailed information. When a new window pops open it conceals the one below on which the last choice was made. This made it difficult for the children to see other choices they had made on a previous window, and also to re-trace their steps. For example Pair 2 had difficulty closing windows, and consequently created all of their quiz questions from one bird type.

• Unequal access to information

The position of the screen and mouse affected the children's access to the information. The laptop was never moved during the session (perhaps because of its perceived value, status, or trailing wires). This meant that one child always had better access to the CD-ROM information than the other. The laptop screen was usually positioned closer to one child than the other, while the mouse was usually controlled by the closest child (see again Figure 3). This often means that the passive child cannot see the screen clearly without leaning over the table in an awkward position. Furthermore their contributions to any search task are limited to verbal directions to the active child controlling the cursor.

Some pairs of children attempted to share the laptop and mouse more equally, with mixed success. Pairs 4 and 6 began with the laptop placed between them so that both children had good visual access to the screen (see Figure 8). However this meant that the passive children in each pair had to lean over their partner's desk space if they wanted to reach the mouse. This caused Fabian in Pair 4 to stand up during the session. Hattie and Ellie in Pair 6 ended up moving the mouse and mat into the center of the table, where Hattie had to use it left-handed (she was right-handed). Pair 2 swapped seats half-way through the session as another way of sharing access to the CD, but this still didn't achieve the same level of collaboration on the task as in the case of the printed book.



Figure 8. Shared access to the screen but unequal access to the mouse.

• Distinct division of labour

A consequence of the unequal access to the CD was that the children tended to assume two separate roles in completing the activities: navigating the CD and writing. This often seemed to result in one child passively waiting for the other child to complete an activity before they moved on with the next task. For example when Sophie and Grace in Pair 2 are creating questions, Grace has browsed to information on the Village Weaver from which she formulates a question. Having conveyed this question to Sophie, she sits and waits, arms folded, as Grace writes down the questions and answer.

• On-screen reading problems

The vertical orientation of the screen meant that there was a lot of looking up at the screen and then down at the paper, and its possible that this made the process of copying from the screen a little more laborious. Also, the child with the mouse often used the cursor to point things out on screen, whereas the child who was writing tended to use their pen to point at the screen. The children did not touch the screen. So behaviours shown in the book session such as using the finger to trace words when reading were not present.

3.3.2 Comments

Children were more forthcoming in giving comments on their experiences with the CD. This is probably because the contents and user models for individual CD-ROMs are more variable and less predictable than those for printed books. Unless the children already had this particular CD-ROM, they were unlikely to understand how it worked straight away and therefore more able to comment on the experience of learning to operate it.

• Need for an opening tutorial

A lot of comments concerned the initial phase of learning how to find your way around the CD-ROM. The consensus was that this is initially difficult but, once mastered, it makes all subsequent activity easy:

G: Once you get the hang of it its easy to get around (Grace, Pair 2). Children with other Dorling Kindersley CDs at home were at an advantage over others in this respect:

E: I've got a space CD that's almost exactly the same so I kind of know the setout and that makes it easier (Ewan, Pair 4).

These discussions usually culminated in suggestions for some form of instructions or tutorial on the opening screen to help them over this orientation process. *G: They could maybe tell you how to get around it at the start* (Grace, Pair 2). Interestingly, there are a series of help instructions available through a small framed question mark hanging on the left hand wall of the opening screenshot. However, this was never selected by the children who tended to be drawn straight into one of the drawers of information relating to Birds.

• Difficulties with hierarchies

To answer the first two questions on the sheet, children had to navigate down through five levels of a hierarchy from the home screen to a 'Key Facts' box describing the characteristics and diet of particular birds. For example, the hierarchy for finding the weight of a Puffin is as follows:

Home -Birds

-Water birds

-Selected species

-Atlantic Puffin

-Key Facts

In reflecting on the process of learning and navigating this hierarchy, the children described a series of false starts, dead ends and 'lucky chances' which eventually resulted in the discovery of the right information:

F: We explored the different category of birds and it was just by chance that we found-

E: -We knew the puffin was a water bird so we, there is a water bird section. First we went into fact file, but it didn't have the right information we wanted, so we went into selected species instead, went to puffin and then to key facts.

I: ...And do you remember how you got the three birds that eat insects?

F: We just did the same as for the puffin I think. We guessed the category, went to that and by luck we found one. (Ewan & Fabian, Pair 4)

Although they seldom complain directly about this process, the children do mention having to 'click through a lot of windows' and work hard to find things

organised in this way. Ironically, there is a search facility that could have taken them directly to particular birds in the hierarchy, located behind a small A-Z icon on the right hand side of the home screen. Only one pair discovered this in the experiment, and quickly left it unused, as they couldn't see what it was for.

3.4 Experiences with the augmented booklet

3.4.1 Behaviour

Use of the augmented booklet exhibited many of the flexible behaviours used with the printed book, but with the addition of multimedia content more typical of the CD-ROM. In this respect it combined the best of both worlds. However, a more detailed look at the course of children's' interactions with the booklet and screen revealed some problems with the interface and content, raising suggestions and issues for design.

• The design of the wand and barcodes

The children often had difficulty swiping the barcodes to trigger the clips. A successful scan depended on a fairly precise swipe action in either direction, starting and ending outside the boundaries of the barcode and made at an optimal speed. Swipes that were too fast, too slow or too short failed to work. Children often helped each other to get a barcode 'working', taking it in turns to have a go and sometimes even holding the wand together as they swiped (see Figure 9). The most effective type of swipe action for children turned out to be a scribble back and forth across the barcode!



Figure 9. Joint use of the barcode wand

Another design issue arose as the children shared the wand. Its wire often became entangled in the pages of the booklet. However the wire attaching the pen to the computer could also be an advantage, keeping the wand in proximity of the laptop. One child used it to reel in the pen, which was out of reach to them! One notable advantage of the wand over the mouse is that it doubles as a pointing device. In one example Ellie uses the wand to point things out on the screen to her partner Hattie (see Figure 10).

• More equal access

The augmented booklet enabled the children to share the tasks and activities evenly and fluidly - as with the book. Even though the child can only access the digital information with the pen, the book is still passed between the children to access the information on the paper. For example, when Alex and Catherine in Pair 1 are just beginning to make up questions, Alex has the wand and the book, but Catherine has an idea. Catherine takes the book from Alex, dragging it across the table, and begins to look for other things. The wand is also shared between the children more than the mouse, and is often passed between the children.



Figure 10. Use of the wand for pointing at the screen.

The booklet also allows the children to perform separate activities in tandem, as with the book. The digital information provides another site for information, which can be used by one child, while the other browses the book (see Figure 11: Lydia is copying from the screen, whilst Iann browses the book). However problems can arise here. In the example shown, Iann decides to look for the next answer to Question 2 while Lydia is still copying down the answer to Question 1 from the screen. In his search, he triggers another clip that removes the clip Lydia is copying. Lydia then talks over the top of the new clip telling Iann to find the original clip she still needs. Once they have done this they return to the clip Iann triggered.



Figure 11. Parallel screen and paper use.

• Control of multimedia playback

Because of the nature of the tasks the children often had to play a clip several times in order to get one word. For example, Ellie and Hattie in Pair 6 were making up a quiz question for their parents. They began by looking for something to make a question from. Hattie pointed at the barcode, and Ellie swiped it with the wand. They listened for a while as a voice narrated some facts about early horses. It says the name of the first horse, and Ellie starts to say something and points at the screen when this is said. She paused, waiting for the clip to finish, but then talked over the top as it ends, telling Hattie her idea for a question ("What was the first horses name?"), and Hattie wrote it down. That done, Ellie then triggered the clip again to catch the complicated name of the first horse (hyracatherium), which as well as being read out, appears briefly on the screen in text. Ellie sees the name and tries to quickly copy it down, but doesn't fully catch it fully. To get the name Ellie and Hattie played the clip 5 times in all, with both of them working on it to try and make sense of it, and get the right spelling. This example also demonstrates another problem that results from the lack of control over the playback of time-based clips. They often have to compete with the narrative to talk over the top of them, or put their conversation on hold as they wait for the narrative to end. Shortly after this example Hattie says to Ellie "Shall we turn the sound down?", and Ellie says, "We can't".

• Predicting hidden information

Children seemed to enjoy the surprise factor of the hidden information often spent time swiping a lot of barcodes seemingly randomly to find out what they would trigger. However several problems arose from the unknown nature of both the content and the media type. In the first place when children are searching for information its not clear to them where they should be lookingthere is no clear division between the type of media or content they will find in the book, and the type of media or content they will find in the clips. Because the content of the clips was not represented on the paper (and the subject of the items in the book and the links were not often clearly matched) children often found it difficult to return to a clip they viewed earlier as there little on the paper to help them locate a specific clip. For example, Charlotte and Maxine (Pair 3) are looking for information to help them create questions for their parents. Maxine uses information on screen to write the question, "Write the name of a famous meat eating dinosaur". Whilst she is writing the question Charlotte triggers other clips, which they Maxine is distracted by. Maxine takes a while to write the question down, and then realises she needs to find the spelling for "Tyrannosaurus Rex". Even though they are still looking at the same page of the booklet Maxine cannot remember which barcode triggered the clip she used and says, "I've forgotten which barcode it was on". They try swiping a few clips, and then Charlotte remembers which one it was.

Because the content of the clips was not represented on the paper children sometimes swiped a link that was not useful, because of its proximity to a relevant item in the book. For example Lydia and Iann (Pair 1) were looking for pre-historic mammals. Lydia spots the elephants and Iann swipes the barcode near them. This triggers a clip about pre-historic species of horse – and Lydia writes "horse" as their first answer. They are then looking for other mammals, and Iann sees the elephants and says that these too would be mammals. Lydia suggests that they swipe the clip to find out, Iann does this, and they get the clip about horses a second time, they both groan and laugh. They then spend some time trying to hunt for the clip about elephants, and after a short time give up, and write "elephants" as their second answer anyway.

Finally because children do not know what media format the clips will take they often come to expect that clips will produce something specific from having seen several clips of a particularly media sort e.g. audio visual media. For example, Fabian and Ewan in Pair 4 are looking for prehistoric mammals. They have seen several clips with pictures and audio. Ewan then triggers a clip that is a text box only, and, even though he sees the text box appear on the screen to replace the other picture, he continues trying to swipe the barcode. After Fabian has a go, they give up assuming its not working and move to another barcode.

3.4.2 Comments

Children's initial reactions to the augmented booklet were generally very enthusiastic. They liked the simplicity of touching the book to fetch extra information on the screen and felt made the booklet more exciting. The following detailed comments begin to unpack these reactions, and go on to critique the approach and make suggestions for improving it.

• Draw and fun of hidden information

Children found the whole concept of hiding extra information behind printed codes very intriguing. This created a psychological pull towards the 'hidden' information and made the scanning activity both exciting and distracting. For example Pair 3 spent a lot of their time just scanning barcodes, compromising

their time to generate quiz questions. Even in the interview they continued to play with the wand, and accidentally scanned a barcode to great peals of laughter. We also noticed that most quiz questions generated by children in this condition were based on screen-based information. This seemed to be based on a belief that hidden screen-based information was somehow more interesting or advanced than printed information:

G: We thought it (the laptop) might have interesting information instead of just what's written in the book (Grace, Pair 2).

• Value of reading aloud

Aside from the instinctive desire to find out what was behind each barcode, children learned to distinguish and prefer certain kinds of screen-based content. A surprisingly strong preference was expressed for spoken content in which the extra screen-based information was read aloud. Many children reported reading the text in time with the voice, and said that this helped them understand the text better. The improved comprehension appeared to result from being taken more slowly and carefully through the text, and having difficult phrases and words spoken in the correct intonation and pronunciation:

L: When it reads it to you I can understand it more... If you read it you might miss a line out or something whereas with that you don't.

I: When it speaks to you, you can follow it much easier. It makes me learn a lot more.

L: Sometimes you might pronounce the words differently, but on there it pronounces them rightly (Lydia and Iann, Pair 5)

Most children wanted the printed text read aloud in this way, but also reproduced on the screen with animated highlighting in time with the speech. Some pairs also indicated the need for control over reading aloud facilities:

E: I like it reading to you but I also like to read it on my own sometimes (Ewan, Pair 6).

• Unreliable barcodes

All the children commented on the difficulty of getting the barcodes to work reliably. Although this was an artefact of the way we chose to simulated surfaceaugmented paper, it did reveal the shortcomings of barcodes when used by children, and generated a number of alternative technology suggestions by the children themselves. These tended to favour a touch-sensitive or gestural interface:

G: You could have wires coming from the book or have quite expensive chips in it or something so that if you pressed a button it would work (Grace, Pair 2) M: You could have electricity on your finger and touch the book and then touch the screen (Maxine, Pair 3).

C: You should have this gadget you just stick in the palm of your hand and just go like that (waves hand over paper), (Catherine, Pair 1)

• Labels for barcodes

Children complained explicitly about the difficult of predicting what information would be generated from any barcode (see also section 3.4.1 above). They also commented on the difficulty of finding black and white barcodes in areas of black and white text. This led to a number of suggestions for labelling barcodes and distinguishing them visually from the surrounding text:

G: You just don't know which barcodes to swipe, and you don't know what information each one has. ... It could be quite good if you had a section here (bottom margin) with all the barcodes in one place... Because we sometimes found it quite hard looking around the pages to find them. They are the same colour as the writing.

I: But then you would need to draw lines to where they relate to

G: Either that or you could have labels (Grace, Pair 2).

E: If on top of this it could say 'Ear here' or something like that, so that you know what information you are going to. Cos on this they are like scattered around and you don't really know what you are going to (Ewan, Pair 4).

• Control of playback

The difficulties of talking over recorded speech and reading animated text (Section 3.4.1), led some children to ask for better control over the time-based clips presented on the laptop. They tended to think of a simple pause or stop button, although the full range of standard multimedia controls might also be useful:

H: I didn't like the way with the horse one it kept going on and on and on. We had to keep going back to the beginning again to get to where we were last time. E: We kept having to go back to try and spell it.

H: I didn't like the way you couldn't stop her talking (Hattie & Ellie, Pair 6).

• Interaction with screen

As a further extension of this kind of multimedia control, some children also expressed the desire to interact directly with screen-based content. This implies a different kind of augmented reading paradigm in which users can move freely back and forth between the paper and screen interfaces, exploring printed or screen-based material at will. A further implication of this paradigm for collaborative reading is that each member of a pair of readers could control different input device (wand and touch-screen/mouse):

G: In my head when we got some information on the screen I was waiting for Sophie to kind of get the mouse and click on something else ... The problem with the screen is that if you read loads and loads and loads of information at once then your eyes can start to water

S: If it's broken up a bit its better (Grace & Sophie, Pair 2).

L: If you could touch press that (reaches over to touch screen) then it could say it for you, or get the mouse and click it on that (Lydia, Pair 5).

• Rich link preferences

When children were asked about their favourite pieces of triggered content they tended to cite links like the 'Reptiles' box on Page 6. This contained additional graphics, text and reading aloud to create a rich multimedia extension to the printed booklet (ID 1, Page 06, x 38, y 45). Other preferred links included the two video clips and the animation on horse evolution. Conversely, the children's least favoured links were the silent text boxes and the 'ears' - audio only icons! In fact, any single -medium link turned out to be a disappointment to children who often recommended adding the missing media types to make them more interesting: *A: It would be good if on those (silent text) boxes they talk to you* (Alex, Pair 1). *M: Ears were a bit boring because they didn't have any pictures* (Maxine, Pair 3).

F: You need pictures. If it's explaining something to you that maybe you haven't heard of before... you might need it to explain it with pictures (Fabian, Pair 4). *I:* If that (bacteria video) had writing next to it with the writing actually saying as well you could follow it and look at the picture (Iann, Pair 5).

3.5 Children's own designs of an augmented page

The children took very quickly to the task of annotating ordinary pages with additional content. They generated 64 links on the 12 pages - an average of about 5 links per page (see Figure 12). The fact that they found this task both easy and interesting is a finding in its own right. It suggests that even children of this age could be assisted to author their own textbooks or notebooks in the future.



Figure 12. Annotations by Pair 2: Grace and Sophie.

A content analysis of all 64 links generated in the design exercise revealed a number of technical features of the 'anchors' and 'associations' used at each end of a link. Figure 13 shows the types of printed items used as **anchors** for links. These include 4 links made up of composite items in which the children had drawn an outline around some combination of image, text and diagram. However, the majority of anchors were single images whose outline was carefully traced to form the active region for triggering an association. The other common category was a block of printed text. This was usually an entire paragraph rather than a collection of sentences. Occasionally section headings were used as anchors for information describing what was in a section. Interestingly, the children never used a single word in the text itself to trigger an association, as we had done to provide definitions in the booklet (pages 1, 3 and 4).



Figure 13. Types of printed items used as anchors for links

Figure 14 shows the types of displayed items used as **associations** for links. These show a spread of selections of video, audio, pictures and text, with audio being the most popular type. The popularity of audio reflects children's interest in having the book read itself aloud to them, and also their desire for ambient sound or commentary with pictures and video.



Figure 14. Types of displayed items used as associations for links

In fact the use of multiple data types per association was another strong finding to emerge from the analysis. This is illustrated in Figure 15 which shows how often composite data types were used within the same association. Children often designed a rich multimedia association as an explanation or extension of some topic or animal mentioned in the booklet. For example Pair 5 linked video, sound, text and pictures to an image of a Rockhopper penguin in order to show how it lives in the wild. What seemed to be requested in these cases was a documentary TV clip, with moving images, ambient sounds and narration.



Figure 15. Incidence of composite associations with multiple data types

In addition to reading aloud text and providing rich extensions, associations were used to bring static images to life, illustrate processes, hear and compare birdcalls, and change perspective on printed images. Taking these in turn, we found that children often used video to visualise some action suggested by an image or diagram or mentioned in the text. For example, the picture of a puffin with fish in its mouth prompted several pairs to design an associated video clip showing how it caught them. In another example, the guillemot eggs were linked to video of the eggs hatching. Textual descriptions of processes such as the swelling of blood vessels in the skin when penguins get hot, often led the children to ask for a visualisation in video or an animated series of pictures. Ambient sounds were requested with most video clips together with narration, but also on their own to express bird calls. The diagram showing a group of birds feeding led one pair to design an audio link comparing birdcalls for all the birds shown. Finally, several children linked pictures to other pictures or video in order to achieve the effect of rotating or zooming in on the printed image to get a better view. This technique was used on the guillemot eggs to inspect egg markings and on various seabird images to see other parts of their bodies.

4. Summary and discussion

Returning to the original aims of the study we can now list some of the strengths and weaknesses of paper, screen and augmented paper resources for reading and learning. These in turn will help us to identify improvements to augmented paper technologies so as to increase their effectiveness and realise more of their potential.

Regarding the properties of the **paper book**, we have found that these supported a wide range of individual and collaborative reading actions. These actions ranged from micro-movements on a page such as turning, flicking, bending, pointing and

tracing, to more macro-movements on the entire book such as tilting, dragging and pushing. The fact that these movements were equally available to both partners at any time in the interaction, meant that the initiative for controlling and discussing information on the task could pass freely between them. This also resulted in a rather fluid switching of tasks roles, where individual children could be writing down answers rather passively at one moment, and turning pages to find particular facts at another. On the negative side, the book was itself perceived to be rather passive and boring in contrast to the CD-ROM and augmented booklet, both of which contained active pieces of multimedia content children could sit back and watch or listen to. Finding information in the book also appeared to be harder work, since there was less opportunity for it to offer up information serendipitously in the same way that the other more active media might.

Regarding the properties of the **CD-ROM**, we found that this afforded a more limited set of physical manipulations through a single mouse and cursor that was seldom shared between pairs of children. This simple fact dramatically closed down the options for mixed initiative control of information on the task. Instead, it created a situation where children fell almost accidentally into the roles of user and assistant, depending on where they happened to be seated at the table. Children fought back against this arrangement by changing seats, moving the screen and the mouse and leaning across each other, but none of these actions were particularly effective in fully equalising access to the information. Furthermore, the hierarchical organisation of content resulted in a rather laboured method of information browsing, involving multiple selections, dead-ends and backtracking operations. Despite, these shortcomings the CD-ROM was the most effective medium for answering task questions (by a slim margin), perhaps because the children adopted such clear reading and writing roles and were so fast at clicking through the hierarchies to the desired information. They also greatly enjoyed the multimedia content available along the way.

The **augmented booklet** fell somewhere in between the book and the CD-ROM as a medium for reading and learning. The children were able to share the booklet equally, as with the book, but also to play multimedia content through the barcode interface. Because two reading surfaces were involved in this arrangement, the children could engage in more parallel reading activities than with a single surface. We also found that the barcode wand, although difficult to master reliably in swiping the barcodes, was easier to share than the mouse. It therefore supported a more equal involvement of both children in controlling screen-based content. Most of the difficulties with the augmented booklet were difficulties of predicting, controlling and consuming this content. Children were initially confused about what kind of content they were going to encounter for any barcode in the book. Without any printed indication, and because of the fun and novelty of revealing hidden information, the children tended to swipe barcodes almost randomly at first to see what was behind them. The lack of pause and mute control over time-based clips was annoying in this phase and beyond, and the omission of media in other clips was disappointing. The most satisfying clips were documentary TV-style clips, using video, audio, text and pictures to expand on concepts in the text. Children later reproduced these types of associations in their own designs, to bring static images to life and explain processes step by step.

In short, the findings suggest that augmented paper has considerable potential to enhance conventional reading activities, by bringing to bear the power of multimedia content in a new way. However to realise that potential, the partitioning of different kinds of content between paper and screen has to be more carefully designed from scratch, rather than reverse engineered from the intersection of paper and screenbased materials designed separately. Augmented paper is in fact a new medium in its own right, and we are at the very beginning of a process of understanding its properties and power. The interface between paper and screen resources also needs re-designing to remove the more obvious usability barriers and generally increase interactivity. One-way of thinking of this is in terms of a continuum between printed books and electronic content, whether on CD-ROMs or the web. Our simulated augmented booklet was too close to the bookend of this continuum and too far away from the electronic end for the children's needs. To move it towards the digital domain appears to require an accentuation of multimedia associations, an ability for the book itself to somehow take initiative and guide the reader through the information, (as in reading itself aloud to the children), and an opportunity to enter into the digital world exclusively so as to follow -up on screen-based information presented at a surface level. This will require more radical versions of augmented paper than we have hitherto explored, where both the paper and the screen-based content are more fluid and interchangeable than the metaphor of a book suggests. In the next section, we list some implications for design that begin to move in this direction.

5. **Recommendations**

The results of the study suggest a number of modifications that might be made to the augmented paper interface technologies and to the augmented paper content of future augmented books. We express these as a series of design recommendations in two lists.

Interface recommendations:

- Make the sensing wand wireless
- Utilise a pointing rather than a swiping action to read wand position
- Add multimedia controls to the wand (e.g. pause/play, mute, volume)
- Provide auditory or visual feedback to indicate the success of sensing actions
- Label active regions with information about the type of associated content
- Provide a touch-screen interface to the screen component of the system
- Explore the use of the paper surface as passive tablet interface to the screen

Content recommendations:

- Think of augmented paper-and-screen content as a new medium for design
- Use paper for text and graphics, use screen for moving images and audio
- For any book, provide an audio version on a separate association layer which can be invoked from any point on the page or text
- Use other layers to provide rich multimedia explanations of the printed text, appropriate to attributes of different user groups
- Provide an active index on paper to facilitate searching screen-content
- Explore custom printing of augmented books from a database search

Acknowledgements

We are grateful to Alan Buckingham and others at Dorling Kindersley for making available the materials used in the study. We would also like to thank all the children who took part, and their parents for help and permission in arranging sessions. Finally we acknowledge the comments and support of colleagues on the Paper++ project, especially Abi Sellen and Rachel Murphy who were involved in planning the study.

References

Adler A., Gujar A., Harrison B.L., O'Hara K. & Sellen A. (1998) A diary study of work-related reading: Design implications for digital reading devices. *Proceedings of CHI '98*:241-248. New York: ACM Press.

Arai T., Aust D. & Hudson S.E. (1997) Paperlink: A technique for hyperlinking from real paper to electronic content. *Proceedings of CHI '97*:327-334. New York: ACM Press.

Back M., Cohen J., Gold R., Harrison S. & Minneman S. (2001) Listen reader: An electronically augmented paper-based book. *Proceedings of CHI 2001*:23-29. New York: ACM Press.

Harrison B.L. (2000) E-books and the future of reading. *IEEE Computer Graphics and Applications*, May/June, 32-39.

Heiner J.M., Hudson S.E. & Tanaka K. (1999) Linking and messaging from real paper in the paper PDA. *Proceedings of UIST '99*:179-186. New York: ACM Press.

Johnson W., Jellinek H., Klotz L., Rao R. & Card S. (1993) Bridging paper and electronic worlds: The paper user interface. Proceedings of Interchi '93: 507-512. New York: ACM Press.

Luff P., Hindmarsh J. & Heath C. (2000) *Workplace studies: Recovering work practice and informing system design*. Cambridge: Cambridge University Press.

Luff P., Heath C. & Greatbatch D. (1992) Tasks-in-interaction: Paper and screenbased documentation in collaborative activity. *Proceedings of CSCW* '92:163-170. New York: ACM Press.

Mackay W.E. & Pothier G. (2001) A-Book: An augmented laboratory notebook for biologists. *ERCIM News No.* 46, July 2001, 52-53. European Research consortium for Informatics and Mathematics.

Masui T. & Siio I. (2000) Real-world graphical user interfaces. In H.W. Gellersen & P. Thomas (Eds.) *HUC 2000*, LNCS1927: 72-84. Berlin: Springer-Verlag.

Nelson L., Ichimura S. & Pedersen E.R. & Adams L. (1999) Palette: A paper interface for giving presentations. *Proceedings of CHI* '99:354-361. New York: ACM Press.

Rekimoto J. & Ayatsuka Y. (2001) CyberCode: Designing augmented reality environments with visual tags. *Proceedings of DARE 2000*.

Robertson C. & Robinson J. (1999) Live paper: Video augmentation to simulate interactive paper. Proceedings of ACM Multimedia '99:167-170. New York: ACM Press.

Schilit B.N., Price M.N., Golovchinsky G., Tanaka K. & Marshall C.C. (1999) The reading appliance revolution. *IEEE Computer 32* (1):65-73.

Sellen A. & Harper R. (2001) The myth of the paperless office. MIT Press.

Signer B., Grossniklaus M. & Norrie M. (2001). Inva framework for database-centric web engineering. *Proceedings of the 4th Workshop on Web Engineering* (in conjunction with the 10th World Wide Web Conference), Hong Kong, May 2001.

Stifleman L., Arons B. & Schmandt C. (2001) The audio notebook; Paper and pen interaction with structured speech. *Proceedings of CHI '2001*:182-189. New York: ACM Press.

Wellner P. (1993) Interacting with paper on the digital desk. Communications of the ACM 36 (7):87-95. New York: ACM Press.

Want R., Fishkin K.P., Gujar A. & Harrison B.L. (1999) Bridging physical and virtual worlds with electronic tags. *Proceedings of CHI '99*:370-377. New York: ACM Press.

Appendix A. The augmented paper booklet.

Document ID 1, Page 01



Page 02





Page 04





Page 06



Appendix B. Design exercise pages

SEABIRDS

MANY SEABIRDS SPEND MUCH of their lives out on the open oceans, and return to land only to breed and raise their young. They nest in colonies along the shoreline or on cliff ledges away from predators. Most seabirds have webbed feet to help them swim, and beaks adapted to catch slippery prey. The sea is a rich source of food for birds the surface water is full of fish, and the shoreline provides worms, crabs, and other shellfish. Some seabirds can remain at sea for more than five years without coming back to land.

ALL-WEATHER OUTFIT

Penguins have a dense covering of feathers, which

Skin when normal



provides waterproofing and protection from the cold. Beneath the skin is a thick laver of fat (blubber) that invulates the penguin, To make its feathers more waterproof the bird applies a special oil with its bill. In hur weather, blood vessels in the blubber swell, bringing body heat to the skin's surface

Blood we

SWIMMING

Most seabirds land on the water's surface to feed, rest, or preen. Only a few swim for long distances. Penguins can make long journeys underwater, but every so often they leap in and out of the water. This technique (called "porpoising") enables the penguin to breathe while travelling at high speeds. Penguins are the fastest swimmers of all birds; gentoo penguins (Pygoscelis papua) can reach speeds of up to 30 kmh (19 mph).

SEABIRD CITIES

Kittwakee neering close together

Many seabirds nest in huge, noisy colonies on cliffs. Colonies provide safety in numbers - there are plenty of eyes to watch for danger, and the mass of birds makes it hard for predators to pick out a single target. Various groups of scabirds nest at different levels on a cliff, dividing the scabird "city" vertically like a high-rise block of flats. Gannets and kittiwakes nest near the top, while cormorants and shags nest lower down.

on buff backpround

arey background

GUILLEMOTEGGS The guillemot, or common imare, does not build a nest. marree, does not build a nest. Instead it hay a single egg on a very narrow cliff ledge. The egg's pear shape helps to prevent it from rolling off the ledge. Individual colours and markings on each egg help the parent bird to recognize to amount bird to recognize to amount bird to recognize 11.00 ong thousands of others

ANIMALS

Rockhopper penguin

SUPREME SEABIRDS Of all seabirds, penguins are the most fully adapted for life in the water. They have lost the power of flight completely and their wings have been modified into flattened flippers to propel them through the water. Penguins have heavier bones than other birds to reduce buoyancy and to make diving easier. Their bodies have become smooth and streamlined to reduce the water's drag, and their thick plumage enables them to survive in very cold waters.

Body is smooth

and straphiled

King périguin divos undeniaste

SALT GLANDS Stabirds have

large salt glands connected to the nostrils, which remove salt from seawater. Although seabirds need some salt in their diets, too much can be harmful. The excess salt runs out of the nearrils and down grooves in the bill, before dripping off the hill tip.

> Approvelyte iclu' factori propel the penguin through the water

Sat gianda

rans down

the eye Saty had

212



Appendix C. Subject question sheet

Questions on Birds

1. How much does a Puffin weigh?

2. Write down the names of 3 birds that eat insects.

3. Make up a quiz for your parents to answer. Write the questions down on the question sheet provided. Write the answers down on the separate answer sheet provided.

For example:

- Q1. How do owls catch their prey?
- Q2. What does a hummingbird eat?

Questions on the Beginning of life

4. When did dinosaurs live on the earth?

5. Write down the names of 3 pre-historic mammals.

6. Make up a quiz for your parents to answer. Write the questions down on the question sheet provided. Write the answers down on the separate answer sheet provided.

For example:

- Q1. What were the first vertebrate animals to live on land?
- Q2. Name a pre-historic plant.

Appendix D. Interview questions

Paper++ simulation study – INTERVIEW David Frohlich, 31.7.01

SESSION 1_____

1. Let's go through your answers.... How did you find that answer? Which were the easiest/hardest questions? Why?

2. What did you think of the book/CD? How could the information have been more interesting? Which parts were the best/worst?

3. Was the book/CD (interface) easy to use? Could you read the words & find things. Did you know where to turn or click on the screen. How would you improve it?

SESSION 2_____PAPER++ BOOKLET

4. Let's go through your answers.... How did you find that answer? Which were the easiest/hardest questions? Why?

5. What did you think of the Paper++ booklet? Did you like the fact that you could get more information from the barcodes? How could the information have been more interesting? Which parts were the best/worst?

6. Was the paper++ booklet (interface) easy to use? Could you get the barcodes to work? What problems did you have? How would you improve it?

7. Which did you prefer, the paper book/CD or the Paper++ booklet? Why?