Digital Bookmark: Seamless Switching Between Printed and Electronic Books

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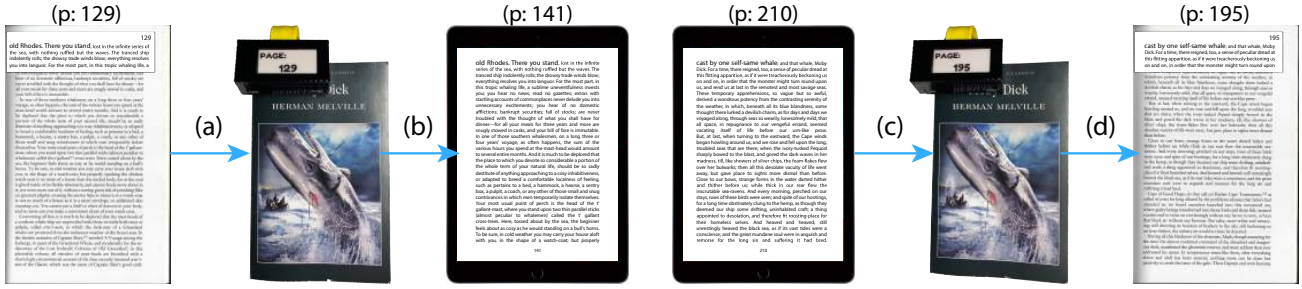

Figure 1. (a) The proposed Digital Bookmark device updates the page number on its display and web server when the user puts it inside the printed book (e.g. page 129). (b) The web server converts to corresponding page number (e.g. p.141) of the e-book and updates it to resume reading. (c) The e-book updates the web server with the new page number (e.g. p.210), ready for switching. The web server converts to corresponding page number (e.g. p.195) of the printed book and updates the bookmark. (d) The user goes to the page displayed on the bookmark and resumes reading. We present the improvement in usability and switching experience using the Digital Bookmark.

ABSTRACT

Recently, people prefer to read books via a combination of formats - e-books along with printed books. We conducted a scoping survey and a lab-study which informed various inhibiting factors associated with switching between formats to conveniently use multiple formats. To improve the switching experience, we present *Digital Bookmark* that synchronises the current page location digitally between both printed and e-books. The page number of the printed book is electronically read using a conductive tag and transmitted to the e-book via the internet. The current location on the e-book is converted to the corresponding page number of the printed book and presented on the display of the Digital Bookmark. We present the results of a controlled lab-study to assess the parameters of switching between printed and e-books. The initial feedback from a local reading group suggests that our Digital Bookmark would encourage multi-format reading and improve their user experience.

Author Keywords

Bookmark, Digital Bookmark, Reading, E-Book, E-Reader, Printed Book, Multi-Format Reading, Format Switching, Book Synchronisation

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CCS Concepts

•**Human-centered computing** → **User centered design;** *Interaction devices;*

INTRODUCTION

With the emergence of the electronic reader (e-reader) and their eventual popularity, it was not uncommon to see the headlines "print is dead" or "death of print" in the news as analysts predicted that digital would become the dominant form to consume published works. Time has shown that print is far from dead. In-fact recent figures have shown the printed book market is growing, while its digital counterpart is shrinking [12, 28]. Many surveys [7, 31, 14], including the scoping survey we present, show the majority of readers have a preference to read printed books over digital. These readers, however, still enjoy the features e-readers bring that printed books cannot, such as being able to search text or access millions of books on a single device.

This preference for print and enjoyment of digital conveniences have led to readers becoming more flexible with their format choice [18]. This flexibility often relates to the readers' current situation. Zhang et al. [35] discovered one might read a printed book in the comfort of their home, but may read an e-reader while travelling for convenience. Companies such as Amazon and Kobo have identified this trend and provide the MatchBook [3] and Shelfie [15] services, which offer discounts to those buying multiple formats of the same book. This growing trend creates the problem of keeping the printed and electronic formats synchronised.

Both printed and electronic books use bookmarking to keep track of the readers' current position. Pearson et al. [24], identified several ways of implementing bookmarks, including ribbons, creating a "dog-ear" (folding down the top corner) or even placing an object within the pages. Bookmarking within an e-book is usually performed by the user-initiated button press. At the time of writing, there is no available method to transfer bookmarks between printed and electronic books. Readers who read the same book in different formats have to find the position when switching manually. We discovered that this could be a mentally demanding and frustrating task as printed and electronic books rarely match page numbers due to different display and font sizes.

In this paper, we first report the results of an online scoping survey on reading format preferences and the switching experience using multiple formats. We explain the scope of improving the switching process. We then report the results of a laboratory study to quantify the switching time and experience. Next, we present a prototype device in the form of a Digital Bookmark for printed books that synchronises the page numbers between the printed and electronic formats. Finally, we present the evaluation of the Digital Bookmark with members of a local reading group. We envision that the concept of a Digital Bookmark could enrich the reading experience.

BACKGROUND

Linking Printed to Digital Documents

The concept of linking physical media to its digital counterpart is not new; research of the area originates as far back as the 1990s. Initial research on linking printed and digital documents implemented hyperlinks and optical character recognition (OCR). The "PaperLink" system (1997) presented by Arai et al. is one such system. PaperLink utilised a prototype "VideoPen" device, which is a modified highlighter pen augmented with a camera to perform OCR. The device allowed any mark made on physical documents to link to a related location in its digital counterpart. "Designing Pen-and-Paper User Interfaces for Interaction with Documents" (2009) a similar and modern approach to this solution is presented by Jürgen Steimle [30].

More recent developments include the Anoto Digital Pen [4] (the early 2000s), a device similar and improved version of the VideoPen demonstrated by Arai et al. The Anoto Digital Pen uses a digital camera, and a distinctive non-repeating pattern dotted paper to recognise where and what the user writes. The device allowed users to create digital copies of their physical notebooks or diaries simultaneously. Since its release, the Anoto digital Pen has been the subject of many research projects, intending to link more forms of physical media to that of its digital counterpart.

Scrapbooking is a method used by many to record precious memories and keepsakes. However, these scrapbooks tend to be bulky and often have a high value to the creator, so their safety and preservation are essential. West et al. [32] presented "Memento" (2007), a system to create digital copies of scrapbooks. Memento identified both advantages and disadvantages of reading from a printed book over its digital counterpart such as tactile feedback and not being able to search content. The system allows digital replication of all content of the physical scrapbook, using the Anoto Digital Pen and a digital camera. This process was one-way, and any changes to the digital document would not appear on the physical version.

PowerPoint presentations are a popular method used to present information, in scenarios such as a lecture theatre or business meeting. In the not so distant past, a presentation was unable to be changed on the fly, and the slide order was linear. "PaperPoint" (2007) [29], is a system which utilises the Anoto Digital Pen to link printed handouts to that of PowerPoint presentations. PaperPoint allows users to control and annotate a presentation while using the pen on paper.

Linking with Modified Paper

Over the past decade, the QR code has become an immediately recognisable icon, even for those with only basic media literacy. QR codes have many uses as they can store up to 3Kb of data. The most common sighting tends to be that of advertising campaigns, where the QR code contains hyperlink data to a product. Research exists using similar methods to link physical documents to digital media. "Embedded Media Marker" (2010) prints almost transparent marks onto paper to signify the availability of new media on a digital device [20]. Linked media includes videos and web pages to add further depth of information presented in the printed document.

Most modern smart devices, such as smartphones and tablet computers, have several sensors so that it can detect the environment around them. One such sensor is the magnetometer, which can detect the magnetic field around the device. Placing magnets around the device can alter the magnetic field, and from this, the device can infer the location of the placed magnets. The "Bridging Books" (2013) [8, 26] project takes advantage of this to offer readers extended content of printed books via a tablet computer. Hidden magnets inside the printed book change the magnetic field around the device, allowing it to detect the current page seen by the user. Readers can interact with the extended digital content via touch, which brings interactivity to printed books.

Conductive inks have become a popular choice to create interactivity on flexible substrates such as paper[23, 13, 19, 10, 33] . One such interactivity is turning the surface of paper into an input device. "Flippin" (2017) [34] uses electronic circuitry embedded in the paper to allow physical interactions on printed books to interact with the digital world. Users could interact with the printed book by touching at specified locations. For example, users could answer a quiz question by touching the paper, and a digital screen would then indicate if they were correct or not.

The above works brought digital features to printed documents. They create a hybrid experience using printed and digital documents together.

Linking with Modified Bookmarks

Positions in printed books, e-books and webpages are kept using bookmarks, which dates back to the 6th century [16]. A bookmark is essentially an address to a location within a

book/document, Ljungstrand et al. [21] developed the "Webstickers" system (2000) which uses one-dimensional barcodes to connect a physical "bookmarked" position to a webpage. WebStickers takes the URL of web addresses and creates barcodes that can be attached to everyday objects. The barcodes, when scanned load the web address associated with them. This allows users to share and organise their physical bookmarks on their printed books via the internet.

Bianchi et al. (2015) explored the use of a physical bookmark like device to support active reading on tablet computers [6]. The device consists of many features including page navigation, screen capturing and visual helping. It uses conductive regions on the bookmark, which can be detected by the touch screen of a tablet, and the application then displays content depending on the context within the bounds of the device.

In our literature search, we did not find a physical bookmark with digital features that could provide bidirectional page synchronisation between printed and digital books. We also did not find the usability and user experience evaluation of such a device. We present a Digital Bookmark that provides bidirectional linking of printed and electronic books.

SCOPING SURVEY

During our background research into the area, we were unable to find any significant data within the field of multi-format reading. Due to this, we decided to run a scoping survey to fill the data gap and discover how widespread the issue of multi-format reading is. We recruited 100 participants (51M, 45F and 4 who preferred not to say) to take part in an online scoping survey, through mailing lists and online survey websites. All participants were over 18, with a median age range of 25-34. We used the survey to discover reader format use, preference, and why, whether or not they own books in multiple formats and how they manage to transition between formats if they do.

89 of participants stated ownership of printed books, making it the most popular format. 66 stated ownership of e-books, and just 21 stated owning an audiobook. We found that 63 of participants owned books in multiple formats, where 61 of those owned books in printed and e-book formats, with the remaining 2 owning books in e-book and audiobook form.

Within the survey, we asked participants if they preferred to use a particular format and why. 71 of them stated a preference for printed books, with physicality (45 participants) and smell (23 participants) being the most stated reasons why this preference exists. 10 participants mentioned that their preference was influenced by having always used and "grew up" with printed books, saying *"A printed book seems more 'real', and it is what I have known all my life"* and *"I am an old school reader"*. These comments originated from all age ranges (18-24 to 65+). 8 participants also stated that their preference depended on the type of literature, where they would read works of fiction digitally and reference books physically as they feel it allows them to comprehend more easily. Research of narrative comprehension between formats exists from several sources [22, 17, 11].

As with previous surveys, [7, 31, 14] and sales figures [12, 28] our findings showed a preference towards reading physical books. We explored multi-format reading, where readers own copies of the same book in multiple formats. Of our participants, 50 stated that they own a copy of at least one book in more than one format e.g. Moby Dick in both physical and e-book formats. 48 of those own a book in printed and e-book formats. We wanted to know if this subset of readers would switch formats while reading a book, for example, read a printed book at home and then continue reading using an e-book in another scenario. 26 participants stated that they identified with this scenario.

Our survey branched participants based on their replies (multi and single format readers). We asked the 26 multi-format participants about the methods they use to ensure they continue reading from the correct location. Printed and electronic books do not match page numbers on a one-to-one scale, due to display and font sizes differing, so it is not a simple case of remembering what page number they currently reside. The method used by 20 participants is to remember events currently occurring within the book. They then flick through the book, reading extracts, looking for a particular event. 3 participants stated they would always try to end reading at the beginning of a new chapter, but stated this was not always practical. The remaining 3 multi-format readers liked to get the books side by side, to be able to compare the content to ensure correct continuation location.

We explored why 24 of our participants would own books in multiple formats and not switch between them. We found that these participants felt that there is no easy way to switch quickly.

In summary, we found that 52 out of 100 participants could benefit from a technology that allows seamless switching between printed and electronic books. We then followed with a laboratory-based experiment to understand the user experience of switching between electronic and printed books in daily life.

FORMAT SWITCHING STUDY

Switching is a complex action to study as it depends on the user preference, prior experience and the use case scenario. We designed the laboratory experiment to analyse the users' time spent switching from one format to another. We believe that this initial experiment would help us understand the switching process outside the laboratory.

Procedure

We recruited 10 participants (3M, 7F, 25-64) for the experiment, from the scoping survey replies, selected from those who identified as multi-format readers. Participants were required to have recently read or currently reading a book in multiple formats. We experimented with one participant per session, each of which lasted 45 minutes. We asked participants to bring a printed book of their choosing and their e-reader device.

We discussed the experiment with an information sheet and proceeded only after being granted informed consent. Each participant then completed a short pre-study questionnaire, which is explained in the next section. We asked them to recall

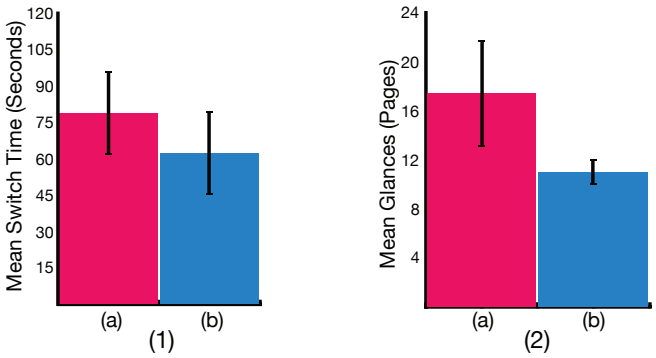

Figure 2. The mean switch-time (1) and glances (2) to locate information in previously read books are shown. Where (a) Switching to print format and (b) Switching to e-book format and error bars show standard deviation

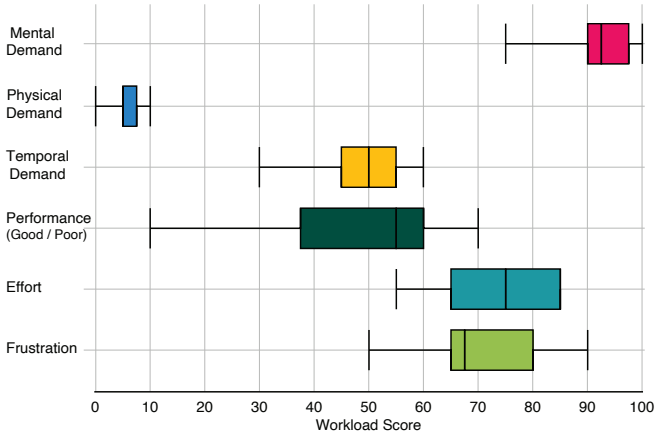

Figure 3. Box plots of post-study NASA TLX assessment, showing the median workload score, 1st and 3rd quartiles along with the upper and lower extremes.

memorable events from their chosen book, which we noted as significant plot points and created a list of 10 events. We randomised the list of events to create the experiment order and to ensure that all experiments were fair, in the case where some participants were able to list events in chronological order, and others were not. Each event in the list was assigned a format switching direction alternating between Print $\rightarrow$ E-Book and E-Book $\rightarrow$ Print, to analyse the time spent switching between each format was measured.

Participants were sat at a table with the printed book and e-reader in front of them, with both showing the title page. We instructed each participant to perform the tasks of the experiment, as described below. After completion of the tasks, participants completed a NASA Task Load Index (TLX) assessment and a short discussion regarding their experience during the experiment.

The tasks of the experiment were video recorded for analysis after the session. Participants were given a £10 Amazon voucher for their time.

Tasks

Using the list described above, the researcher called out a reading format and the event for the participant to locate.

The participants would then use any means at their disposal (mimicking their current method of switching formats), such as the search function or table of contents, to locate the information as if they were going to reread that section of the book. The task involved finding the beginning of an event that spanned multiple pages or the paragraph containing shorter events. Once found, the participants showed the location to the researcher to confirm.

Following this, the participants were allowed a short time to familiarise themselves with the event and surrounding information. Our interest lies in the second stage of each experiment, where participants were required to switch formats. We instructed the participants to close the book or return the e-reader to the home screen and find the same event in the alternative format; during this stage, we took several measurements which are given below.

Each participant performed the task a total of 10 times, where each time the switching direction would alternate with a different event to locate.

Measurements

During each task, we recorded the time taken, and pages glanced at to find events, allowing us to analyse the effects of switching direction.

We recorded qualitative data of the technique each participant used to locate the event, which we obtained via analysis of the video recordings of each session.

Finally, at the end of the study, we performed a NASA TLX assessment (administered using the NASA TLX iOS application) to measure workload during the task and also recorded what format they thought was easiest to find the information.

RESULTS

Pre-Study Questionnaire

The pre-study questionnaire consisted of three questions. The first two questions helped us understand the *use* and *preference* our participants had toward reading. For the use case, all 10 of our participants stated that they read from printed books regularly. 8 participants stated that they also regularly read from e-books. Just 3 participants declared that they also listen to audiobooks along with reading from printed and e-books.

8 of our participants preferred to read printed books with the remaining 2 preferring e-books.

For the final question, each participant declared the number of times they had read the book, to see whether it affects information retrieval. 8 of our participants had brought along a book that they had read to completion once. The remaining 2 participants had read their chosen book twice.

Task-Based Study

Switch-Time: We considered the *switch-time* as the performance metric to analyse the tasks. It is the time taken to locate the information needed while switching from one reading format to another. We present the results in Figure 2, where the

average switch-time for switching to printed books was 79 seconds (min - 4s, max - 7m47s), and switching to e-books was 62 seconds (min - 13s, max - 5m37s).

We analysed the switch-time of both printed and e-books using repeated measures ANOVA (RM-ANOVA) using the R environment. We found a significant main effect of switch-time ($F_{1,98} = 1.24763$ and $p < 0.01$)

Switch Technique: Participants used a binary search-like technique, where they opened the printed book on a page they "felt" was in the general area. They would then read small extracts of a paragraph, enough to understand what was going on and then move in the direction they believed the event would be. This technique would repeat until the participant found the correct information on the page. 3 participants used this approach to find the information in the e-book version; however, most understood the features of an e-reader well and chose to use the search function to find the general area and then proceed with the binary search technique.

Glances: We define a glance as the participant's pausing to actively read an extract of a page, which were counted during the task and verified via the video recordings. The mean number of glances performed while switching to printed format was 17 (min - 1, max - 122) and 11 (min - 1, max - 83) while switching to e-book.

We analysed the number of glances while switching to both printed and e-books using an RM-ANOVA using the R environment. We found a significant main effect of glances ($F_{1,98} = 3.84538$ and $p < 0.01$)

The switch times for switching to printed books showed to be the highest, with the average time being 17 seconds longer and the difference in the greatest times being 2 minutes 10 seconds, which if done several times a day will soon add up. Switching to printed books also had participants performing more glances, with an average of 17, 6 more than that of switching to e-books. Our Digital Bookmark looks to decrease this time drastically and to remove the need for readers use of memory while reading on different formats.

We analysed whether the difference in turning a physical page or flicking through an e-book affected switch times. We found that the benefits/drawbacks of each format were able to balance each other out. E-books can switch pages faster, but only a single page at a time and physical books can have multiple pages skipped.

Post-Study NASA TLX Assessment

The post-study NASA TLX assessment looked to measure mental demand, temporal demand, performance, effort and frustration participants felt the tasks. We present the NASA TLX results in Figure 3.

- Mental demand had a median workload score of 92.5, demonstrating that the task of switching from one format to another is mentally demanding. Discussions with participants revealed they felt it was mentally demanding because they had to remember the order of events leading up to the event they were seeking, as it helped them to locate the required event; 8 participants described this sentiment.
- Scores for physical demand were opposites, with a median workload score of 5, demonstrating that the task was not a physically demanding one.
- The temporal demand assessment yielded a median score of 50. The discussions revealed that participants sense of temporal load increased the longer they took to complete a task. Participants who completed the tasks faster had lower workload scores for the temporal load.
- The scores of participants' perceived performance correlated with the time taken to perform a task. The faster a participant was able to complete a task, the lower the perceived performance score (where lower means better). The median performance score was 55, with a lower extreme of 10.
- Overall, the participants found that the task required much effort, with the median workload score for the effort being 75. This effort was felt unanimously by the participants as a result of the mental demand the task required.
- Participants found the task to be quite frustrating, with a median score of 67.5. Participants found their search technique particularly frustrating, as their first estimate either fell before or after the event they were seeking where all future searching relied upon their memories of the first seen position.
- Overall the participants found the task needed high mental demand and was frustrating, and our discussions revealed several reasons why.

DIGITAL BOOKMARK

The online scoping survey and the laboratory study showed that switching between printed and e-book formats are mentally demanding, frustrating and time-consuming. Participants like to read both printed and electronic books, and like the advantages of both formats. However, there is a gap that needs bridging which will make switching between the formats easy, quick and thereby enjoyable.

We present the Digital Bookmark device for printed books (Figure 4). It allows easy and quick synchronisation of progress between book formats. We attempted to mimic the experience of using a bookmark in a printed book, where a user places it onto the current page.

When inserted into a printed book, the Digital Bookmark detects the page number and notifies a web server, allowing digital devices to retrieve this information when needed. Many digital devices already use a similar feature to keep themselves in sync with one another, and the Digital Bookmark allows printed books to become part of this ecosystem.

The Digital Bookmark has an e-ink display which shows the readers current page number on the web server. It allows progress made on electronic books to be continued on the printed version seamlessly, removing the necessity for readers to remember the current reading location in their electronic books.

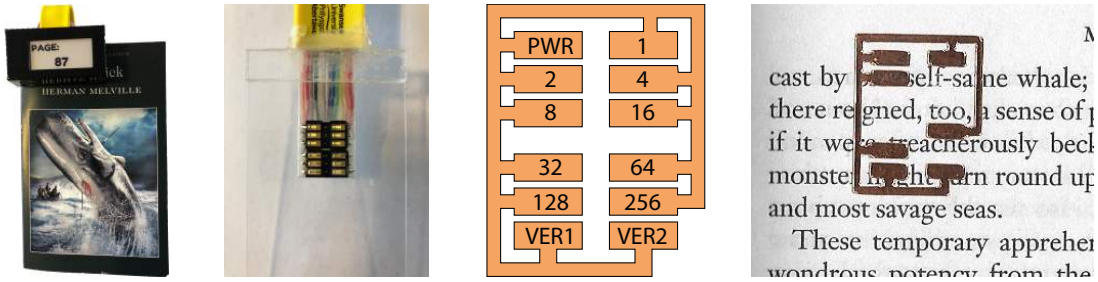

Figure 4. (a) The Digital Bookmark is shown placed inside a book. (b) The conductive tag and reader is shown. (c) The conductive tag design is shown. VER 1 & 2 are used to verify correct placement. Numbers on each contact pad represent the decimal weight of each binary bit. (d) Conductive tag shown on a page of a printed book could be placed in the top margin..

PROTOTYPE

We built a prototype Digital Bookmark using off-the-shelf components, including a Raspberry Pi Zero W [9] and an Inky pHAT e-ink display module [25]. We also created an e-reader application using FolioReaderKit [1] as its foundation. The Digital Bookmark and e-reader application synchronise electronic versions of books to their physical counterparts or vice versa.

Hardware

The bookmark consists of two parts: the controller and the reader. The reader, shown in Figure 4 (b) has a similar size and shape as a conventional bookmark, designed this way as it is the part which placed inside printed books. Sim card readers are used to read the contact pads of a conductive tag on the paper which we described below.

The controller, shown in Figure 4 (a) is the primary unit of the Digital Bookmark and houses the Raspberry Pi Zero W, Inky pHAT e-ink display and the battery. The display informs the reader of the page number that they should resume reading from, and updates whenever the synced page in the web server changes. The controller converts the binary data read by the reader to a decimal and transmits it to the web server via WiFi.

The design of the Digital Bookmark mimics the experience of using a conventional bookmark, with the addition of a display. We considered several different methods during the conceptual stage of prototype development, including manual page number entry. However, ultimately we decided that from a user experience perspective, automatic page detection would fair better. With a current physical bookmark, a reader simply slots it into the next page to read, one simple step. Manual page entry would have required some extra steps, such as looking up the page number and entering it into some device. We envisioned a method in which users could replace existing bookmarks with no learning curve. To use the Digital Bookmark, the user would slot the tag reader on the page they wish to bookmark. To resume reading, they would read the page number from the display and flip the pages to that location.

E-reader Application

The application design is to recreate the look and feel of any standard e-reader application on the market, such Apples' iBooks [5] or Amazons' Kindle [2]. When the application enters the background, the current position of the e-book is synced to the cloud to allow seamless continuation. When brought into focus, the application presents the user with the latest synced page across devices and printed books.

Conductive Tag

We tagged each page with a conductive substrate (shown in Figure 4 (c & d)) to detect its number with the Digital Bookmark. Each tag has twelve contact pads, where one pad conducts power, two pads verify the correct placement of the Digital Bookmark and the remaining pads form a 9-bit binary representation of the page number. Expansion of the system is possible by adding more read points to the bookmark to allow the reading of higher numbers.

Content Synchronisation

In order to display an e-book, e-readers dynamically paginate the content taking font and display size into account. An e-book contains no information regarding the pagination of printed copies of itself, and the device needs this information in order for synchronisation to take place. Tags were added to the e-book to create page-markers of the physical pages of the printed book. A script to add the tags was created, which:

1. Extracts the content of the e-book
2. Paginates the content to the same parameters as the printed book
3. Injects page-marker tags into the e-book

The tags allow the application to identify its current location in regards to the printed book, where it merely searches for the first page-marker tag behind the first word displayed by the e-reader.

Limitations

By far, the most significant limitation of this implementation is the need to tag pages of printed books, and the process is time-consuming and impractical for all existing books. New books could have the tags added during the printed process with transparent conductive inks, but this would incur a cost and exclude all existing books. For those reasons, we believe that this hardware solution is not ideal and would need evolving if it was to become available to the mass market. This solution was not the only method investigated.

We investigated the use of OCR in order to read the content of printed pages to infer location. We found that this method is entirely possible. However, it comes at the cost of incredible user experience. We wanted the bookmark to mimic the current experience as closely as possible, where a user places a bookmark into a book with very little thought and effort, which is valid for our current implementation. An OCR implementation required far more thought and effort from users, where the experience was severely unnatural and required the user to actively use the bookmark to synchronise the page, where a camera would take a picture of the page. The image of the page needs to be in focus, resulting in an experience that involves picking up the bookmark, activating the camera, focusing the camera, waiting until the image is captured, verifying the OCR worked accurately and then placing the bookmark in the book. For this reason, we chose to implement the current prototype to investigate if the concept of the Digital Bookmark could work and improve the user experience for multi-format readers.

DIGITAL BOOKMARK STUDY

We ran a study with a small local reading group to get the Digital Bookmark device into the hands of the users. The study aimed at getting Digital Bookmark user evaluations from each participant, as well as thoughts and ideas of how to improve the device in future iterations.

Procedure

The reading group had 10 members (6M, 4F, 18-64) who were able to take part in the study. The reading group was selected as each member is an active reader who often read several books over many formats. We designed the study to show how Digital Bookmark works, demonstrate how it can speed up the format switching process and remove readers use of memory for finding their current position across formats.

We discussed the experiment with an information sheet and proceeded only after being granted informed consent. Each participant completed a short pre-study questionnaire for demographic and reader use/preference purposes. Participants sat at a table which had the printed book, e-reader and Digital Bookmark placed upon it, with both books showing the title page and the display of the Digital Bookmark showing zero. We instructed each participant to perform the tasks of the study, as described below. After completion, participants completed a NASA TLX assessment and a short discussion regarding their experience during the experiment and of the device.

On completion of the study, participants were given a £10 Amazon voucher as compensation for their time.

Tasks

As the bookmark requires a tagged book, we performed this experiment using a book of our choosing (Moby Dick by Herman Melville). Because of this, instead of finding 10 known locations, this study had participants going to any random location within the book and then verifying that the bookmark or e-reader seamlessly displays the same content.

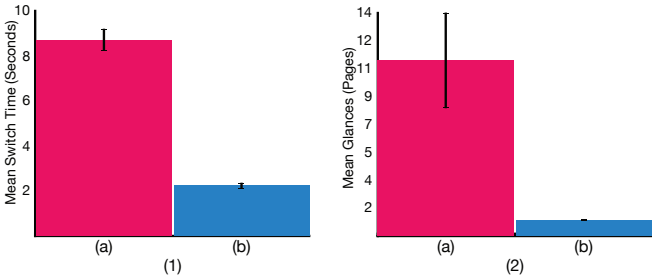

Figure 5. The mean switch-times (1) and glances (2) while using the Digital Bookmark are shown. Where (a) Switching to print format and (b) Switching to e-book format and error bars show standard deviation

To match the number of data points as the previous study, the participants had to perform the task of switching from one format to another 10 times (5 x print to e-book, 5 x e-book to print alternately). When switching from the printed book to the e-reader, the participant had to place the bookmark into the page they chose and then opened the e-reader application to verify the content was synchronised and the same. When transitioning from the e-reader to the printed book, the participant navigated to a page of their choosing and returned the e-reader device to the home screen, they then checked the bookmark display and verified that the content on the displayed page was the same. Like the previous study, we recorded the time taken to analyse whether the bookmark speeds up the process.

STUDY RESULTS

Pre-Study Questionnaire

Again the pre-study questionnaire was aimed at getting the reading preferences of our participants, where 8 of participants declared the use of printed books, 7 declaring e-book use and just a single participant using audiobooks. The preferred format of participants closely resembled that of the previous study with 7 preferring printed books and the remaining 3 preferring e-books.

Task Based Study

Switch-Time: Like in the format switching study, we considered the switch-time as the performance metric to analyse each task. We present the results in Figure 5, where the average switch-time for switching to printed books using the Digital Bookmark was 8.92 seconds with a minimum of 2 seconds and a maximum of 15 seconds. The average switch-time for switching to e-books using the Digital Bookmark was 2.38 seconds with a minimum of 1 second and a maximum of 4 seconds. During each task, the Digital Bookmark presented the correct page to the participants almost instantaneously. The time variance occurred and shown here is the time the participants took to confirm the correct event location in the book.

We analysed the switch-time of both printed and e-books using an RM-ANOVA using the R environment. We found a significant main effect of switch-time ($F_{1,98} = 1.24763$ and $p < 0.01$)

Switch Technique: While using the Digital Bookmark, all participants demonstrated an entirely different search technique while looking for the location within a printed book. As the task had now switched from an information-seeking task to merely seeking a page number, all participants used the "flick" technique. The "flick" technique involved the participant holding the book with their thumb securing the edges of each page and then bending the book to release the pages at the top of the stack. The flicking caused swift turning of pages while readers monitored the page numbers. Participants would then stop the flicking process either directly on the correct page number, or within a few pages, and then simply turn to the correct page.

While switching to the e-book, no switch technique was required, as the correct page was always instantly presented to the participant.

Glances: For this study, we had to redefine a glance as the participant only actively read an extract of the correct page. So for this task, a glance was defined as a participant's pause in the search to read a page number or an extract actively, which were counted during the task and verified via the video recordings. The mean number of glances performed while switching to printed format was 11 (min - 1, max - 17) and 1 while switching to e-book.

We analysed the number of glances while switching to both printed and e-books using an RM-ANOVA using the R environment. We found a significant main effect of glances ($F_{1,98} = 252.5$ and $p < 0.00001$)

Post-Study NASA TLX Assessment

We conducted the NASA TLX assessment to measure mental demand, temporal demand, performance, effort and frustration participants felt the tasks. We present the NASA TLX results in Figure 6.

- Mental demand had a median workload score of 5, demonstrating that the task of switching from one format to another using the Digital Bookmark is not mentally demanding.
- Scores for physical demand had a median workload score of 5, demonstrating that the task was not physically demanding.
- The Temporal demand assessment yielded a median score of 10. As each task took very little time, each participant felt very little demand.
- The median score for performance was 10, where a lower score means a better perception of performance. The correlation that was seen in the format switching study continued, where the faster a participant was able to complete a task, the lower the perceived performance score.
- Participants found that the task required minimal effort, with the median workload score for the effort being 10. The task required very little mental demand, this then carried over to the effort the participants required to complete the task.
- Participants found the task was not frustrating, with a median score of 5. Participants felt that the task was least frustrating when switching to the e-book format, as the e-reader instantly presented the correct page. Participants felt slight frustration when switching to the printed format.

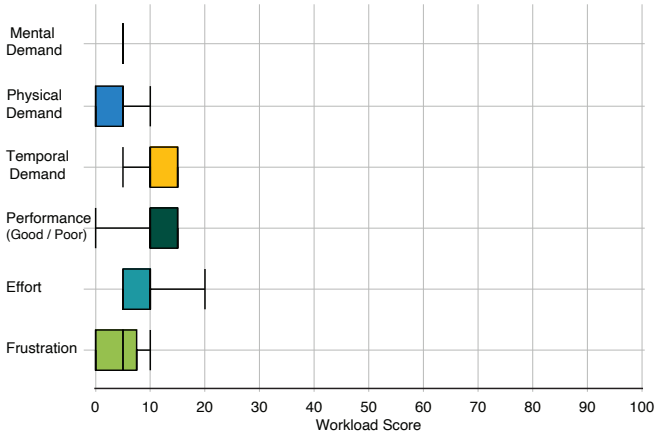

Figure 6. Box plots of post-study NASA TLX assessment, showing the median workload score, 1st and 3rd quartiles along with the upper and lower extremes.

- Overall the participants found the task needed minimal mental demand and was not frustrating.

Post-Study Discussion

Following the NASA TLX assessment, each participant took part in a discussion regarding their feelings of using such a device, topics involved form-factor, usability, and whether they could incorporate such a device into their reading. We had several comments regarding the form factor of the device, such as it being significant in size for a bookmark. We were expecting as the device was constructed using shop-bought components and were not demonstrating a finished product, but a prototype for an exploratory study. Participants liked the fact that we attempted to mimic current bookmarks as it is quickly recognised, with one participant stating "as soon as I picked up the device, I knew how to use it." Participants unanimously agreed that being able to transition between printed and electronic formats instantly could improve their user experience while reading multiple formats. Participants also unanimously agreed that they could incorporate such a device into their daily reading, with some improvements to the device, such as a more slimline form factor and the ability to use on any book.

DISCUSSION AND FUTURE WORK

Our format switching study has shown that switching from one format to another can be a mentally demanding and frustrating task, even when doing so in a short time frame in a controlled lab environment. In this environment, we were unable to reproduce the real world distractions we receive as part of daily life, such as interactions with others or concentrating on other tasks. These interactions and distractions may make the task even more difficult in a real-world scenario.

Most books have page numbers on each page. Unfortunately, page numbers of printed and e-books do not match, due to several factors such as screen and font size. The Digital Bookmark allows readers to seek these page numbers on printed books as the device converts the digital position to the corresponding printed page number. The Digital Bookmark eliminates the

seeking task all together for switching to e-books, seamlessly presenting the correct location.

Participants felt that the process of switching using the bookmark required very little mental demand and presented very little frustration. These results differed significantly to the study we held performing the same task without the Digital Bookmark. When discussing the device with participants we received feedback that the control unit was "bulky", this was somewhat expected with a device made from shop-bought components and traditional bookmarks simply being a narrow piece of card or leather. Future iterations of the device could easily allow a smaller form factor using custom-built electronics, rather than using off-the-shelf components. Initial feedback from participants indicated that they believe that a Digital Bookmark would improve their user experience across multiple formats.

In its current state, the Digital Bookmark requires tagged pages in printed books in order to read the page number. Although the current method allows the bookmark to synchronise printed and e-book formats successfully, it is somewhat impractical due to books needing to be tagged. Future books could have conductive tags applied during the printing process. However, this would exclude the billions of books already in circulation. Future iterations of the device will look to implement a natural solution using OCR, allowing the possibility of synchronising books with their digital counterparts without the need to tag. Using OCR would allow readers to synchronise all printed books within existing libraries, adding backwards compatibility.

The Digital Bookmark only synchronises printed books and e-books. It is entirely possible to include audiobooks in the synchronisation ecosystem, using open source libraries such as Aeneas [27] that allow the synchronisation of e-books and audiobooks through forced alignment.

Overall, a direct comparison of the format switching and Digital Bookmark studies is impossible as they are fundamentally different tasks. However, each study looks at the same problem - switching between reading formats. The Digital Bookmark has shown a drastic 90% reduction in switch-time, compared to the bookmark not being used when switching to printed books. The Digital Bookmark has shown an even more drastic reduction of 97% in switch-time, when compared to the bookmark not being used when switching to e-books. These massive reductions in switch times show that such a concept is worth investigating and developing further.

We can visualise a reduction in the workload scores between the format switching and Digital Bookmark studies (again, not directly comparable). These show that if a Digital Bookmark concept were to be developed and deployed an improvement in the user experience is possible.

CONCLUSION

We presented the concept of a Digital Bookmark device for seamless synchronisation and transition between printed and electronic books. Due to the lack of prior work, our online survey helped scope the research and development for improving usability and user experience of reading books in multiple formats. It mainly identified the use of memory and a lack of a seamless switching method as inhibiting factors when choosing to read via multiple formats. Consequently, we designed a simplified laboratory study to quantify the switch-time and task workload required to switch between formats. We then devised the Digital Bookmark to address the main inhibiting factors of switch-time and memorising events and help understanding the switching process and its user experience. We present the results of a small group user study of Digital Bookmark and reported significant improvement in switching time and task workload. Participants also reported improved user experience in multi-format reading. We conclude that a Digital Bookmark for seamless switching is required as it would significantly improve the transition experience between printed and electronic books.

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