Mixed Reality Book

Immersive Content Consumption

Using Projected Periphery

Aleksandr Ruiz
Abstract

This report covers the methodology, research, and design process of my Thesis Project I: The Mixed Reality Book. The project is a proof-of-concept system that adds contextual periphery effects to regular paper books, using Spatial Augmented Reality. The intention is to enhance reading experiences within public libraries – amongst children and students. In this brief study we investigate how Projected Periphery can create, improve, and augment reading by manipulating the physical book, and the area around it, using projections. Throughout the study, I conduct design engagements, rapid prototyping, and workshops with the intention of identifying meaningful interactions. Two primary contexts of use are identified and analysed with an emphasis on developing usable design conventions and laying the foundation for a Mixed Reality Book system. The result is a working prototype, analysis of the research and challenges, and an exploration of how this technology could be shaped further and deployed.

Author’s Keywords:

Spatial augmented reality, projection mapping, immersion, cinematic reading

ACM Classification Keywords:

Multimedia Information Systems: Artificial, augmented, and virtual realities
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1. INTRODUCTION

The book remains one of the most important conveyors of information and knowledge, even on our modern age (Hom, 2016). Even though advancements in computer technology and miniaturisation created new ways to read and consume text, traditional books are highly regarded in most contexts of daily life and education. We have seen the development and wide adoption of tablet computers, e-ink readers, and audiobooks throughout the decades. This type of technology is incredibly convenient, considering it can be deployed massively using the internet, removing all spatial and physical limitations on how much text can weigh, allowing consumers to store thousands of e-books on their e-readers.

Unfortunately, in a world of multimedia - due distractions, questionable reading ergonomics, and unfulfilled potentials of technology, reading digitally is widely considered less effective. In fact, e-books have stagnated in terms of technology, and are viewed as a failure by some book publishers (Alison Flood, 2018). As the years pass, technology is improving, especially within the emerging fields of Mixed Reality, Augmented Reality, Motion Tracking, and Projection, which allows for deeper experimentation on what reading can be.

Moreover, we can observe a trend of interacting primarily with screen-based glass interfaces. Even though our somatosensory system, and our fingers, have evolved to be able to feel a vast array of different sensations (Robles-De-La-Torre, 2006). This is pointed out in the article, A Brief Rant about the Future of Interaction Design (Victor, 2011), which has served as a foundation for this project so far; this is further elaborated in the Argument for a Traditional Book, section 2.4.

This report focuses on the use of Spatial Augmented Reality (SAR) and Projected Periphery (PP) to create a more ergonomic and mediated experience for our target audience. An analysis of the current technological capacity, and research within both SAR and PP is performed with an intention to construct a SAR reading prototype. The prototype explores 2 potential contexts of interaction, as well as collecting the opinions and workshop results throughout. The purpose of this 2-month project is to lay the foundations of a potentially new category of reading experiences using Spatial Augmented Reality.

This paper offers the following propositions:

- Analysis of the reading environment and conditions
- Implementation and description of the Mixed Reality Book prototype
- Testing of 10+ different usability concepts and collecting the results
- Analysis of the design space of the augmented reading experience
- Deploying a prototype in real-world scenarios and exploring it with users in actual use situations
- Discussion of the workshop feedback, findings and new ideas
- Identification and consolidation of Strong Concepts into Interaction Categories and Insights
- Considerations on potential new branches using this technology
- Conceptualization of a portable and miniaturized variation of the device

1.1 Research Question

Originally, the project was intended to be carried out entirely using Virtual Reality and Augmented Reality. However, during the discovery phases it has been identified that Spatial Augmented Reality provides a more interesting, albeit a more challenging, avenue of pursuit (Figure 1). SAR is a more interesting concept to work with in our context, as it does not isolate the user from their environment in the way that VR does. This provides a more authentic experience that does not require any wearable devices. Moreover, because of the isolating nature of VR, SAR was chosen because of its affordance for social interaction and co-play. Additionally, because of the relatively low-tech state of current-generation VR, it’s difficult to provide arguments for VR reading currently. After identifying the key elements in the Discovery phase I decided to continue with Spatial Augmented Reality.

The research question underwent a lot of re-framings; what originally emerged as an HCI-styled engineering challenge was re-grounded as the following:

- Analysis of the reading environment and conditions
- Implementation and description of the Mixed Reality Book prototype
- Testing of 10+ different usability concepts and collecting the results
- Analysis of the design space of the augmented reading experience
- Deploying a prototype in real-world scenarios and exploring it with users in actual use situations
- Discussion of the workshop feedback, findings and new ideas
- Identification and consolidation of Strong Concepts into Interaction Categories and Insights
- Considerations on potential new branches using this technology
- Conceptualization of a portable and miniaturized variation of the device
How can we design interactivity for SAR reading at a public library?

Related questions include:

- Which kinds of interactivity and visual aesthetics enable a rich SAR reading experience?
- How could this new content consumption strategy be used with different types of literature?
- How can this technology be used beyond libraries and academic environments?

Figure 1. The discovery probe that grounded SAR as the focus point (yellow)

For the simplicity of the reporting, the project is described in four main stages – Theory, Method, Design Process and Conclusion, with an addition of Appendices detailing less relevant but important elements. Each part describes the thought process and the development, with an emphasis on the outcome of the prototyping, research through design via the 10 “mini-studies” (11.2), and 2 major workshops (4.3). In an iterative process, each phase and progression of this project had an influence on the next phase, which in turn contributed to the (re)framing of the project, the research question, and the development of more engaging concepts.

1.2 Users and Stakeholders

The project has the capacity to envelop a diverse range of industries and use situations. Originally, the concept was intended to focus on recreational reading amongst young adults. However, after re-framing and identifying contexts of use, the attention was drawn to the libraries, both public and within educational establishments. Therefore, the primary stakeholders will include children and students, based on the design openings of this project. Secondary stakeholders will be teachers, librarians, illustrators and parents. The workshops allowed for my collaboration with these stakeholders in the design and development of the project.

1.3 Inspirational Incident

I considered the possibility of a Mixed Reality Book long before I knew how to use a computer. I would like to attribute the inspiration for this idea to Disney’s Treasure Planet, which was released in 2002 and features a scene [12.1, (Figures AC1.1-1.4), video] where a mixed reality holographic book is used to tell a story. That scene resonated with me for well over a decade and culminated in this opportunity to work towards wielding that dream into a reality, using the technology that is available today. Even more fascinating is the perspective of Interaction Design on this dream; the synthesis and imagining of how it could be in the future.

2. BACKGROUND/THEORY

2.1 General

To paint a picture of the first idea behind the Mixed Reality Book, we can imagine sitting down in the living room, perhaps on the couch, to read a book. When the book is opened, the area surrounding us magically transforms into a peripheral experience, where projected content appears in, and outside of, the book. This content may be a flock of crows flying around when one is reading The Raven (11.2.1), or a subtle snow or rain effect matching the mood of the page that is being read. The content can vary considerably, and may even include simple colours and effects, based on the scan of the room. These are just a few of the many interaction scenarios that could be possible with the mixed reality book, utilizing spatial augmented reality. In the next sections, we will consider the different aspects and conditions necessary for these interactions to be meaningful.
2.2 Ergonomics

First and foremost, let us consider the ergonomics of reading. In modern times, reading happens at almost every possible time and place, thanks to smartphones. However, due to the current limitations of SAR technology, we must also limit ourselves to more stationary means of reading; I identified the following scenarios where we can analyse the ergonomics of the reading situations (Figure 2). The scenarios were inspired from “The Cornell Digital Reading Room Ergonomics Checklist: Development and Evaluation” (Brynjarsdóttir, 2007).

Table 1. Reading Ergonomics

<table>
<thead>
<tr>
<th>Reading sitting down</th>
<th>Reading while standing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chair-specific</strong></td>
<td><strong>Desk-specific</strong></td>
</tr>
<tr>
<td>Correct Leg Height</td>
<td>Head Tilt</td>
</tr>
<tr>
<td>Neck Support</td>
<td>Elbow Position</td>
</tr>
<tr>
<td>Shoulder Support</td>
<td>Wrist Position</td>
</tr>
<tr>
<td>Chair Height</td>
<td>Forearm Position</td>
</tr>
<tr>
<td>Adjustable Properties</td>
<td>Lumbar Support</td>
</tr>
<tr>
<td><strong>Desk-specific</strong></td>
<td><strong>In-Line Reading and typing</strong></td>
</tr>
<tr>
<td>Head Tilt</td>
<td>Desk Height</td>
</tr>
<tr>
<td>Elbow Position</td>
<td>Desk Angle</td>
</tr>
<tr>
<td>Wrist Position</td>
<td><strong>Adjustable Properties</strong></td>
</tr>
<tr>
<td>Forearm Position</td>
<td>An adjustable sitting/standing desk, with the capacity to change its angle, is highly recommended for this project, but this is beyond our control.</td>
</tr>
<tr>
<td>Lumbar Support</td>
<td></td>
</tr>
<tr>
<td>In-Line Reading and typing</td>
<td></td>
</tr>
<tr>
<td>Desk Height</td>
<td></td>
</tr>
<tr>
<td>Desk Angle</td>
<td></td>
</tr>
<tr>
<td>Adjustable Properties</td>
<td></td>
</tr>
</tbody>
</table>

To maximize the comfort of the peripheral reading experience, all general conventions of ergonomics of the furniture should be observed. The project, however, is limited to the furniture available in our spaces; in this case, we will rely on the notion that the desks and chairs at the libraries conform to certain minimums of ergonomics.

Certain properties of ergonomics affect both scenarios; here are the common elements that should be considered in the spaces where the project is used:

**Environment-specific**
- Light and illumination
- Ambience
- Acoustics
- Air quality
- Temperature
- Interior properties
- Ceiling height

**Collaboration-specific** ergonomics may include the following:
- Desk size
- Desk shape
- Desk height when standing up
- Desk roundness
- Availability of chairs
It’s important to note that due to the lumen efficiency limitation of the prototype projection system, a dimly lit room and a completely clear white table were two of the main prerequisites. The design of the prototype and studies were conducted in a similar environment; while not ideal, a more modern projection solution would solve this problem (this is detailed in the hardware challenges section 6.3).

2.3 Environment Metadata

In our project, we are focusing primarily on libraries in the Baltic and Nordic countries. An important aspect of the Mixed Reality Book is the retention and rendering of the Metadata. Metadata is an important concept in a study environment, and indeed, in this project, because it provides information about information. For the Mixed Reality Book prototype to successfully provide meaningful experiences, it must be bundled with a database that contains information about the media that’s being consumed. Because the technology, at a concept, relies on identifying existing books using OCR\(^1\) and/or RFID\(^2\), we need to consider a method in which metadata could be bundled with the identification process. For example, if a book about human anatomy is placed on the table, the Projected Periphery would show additional content on the table based on the metadata it finds in the database. We can work on the assumption that modern libraries already have a digital book database with, at the very least, rudimentary classification systems and/or RFID.

To help with further metadata considerations, the International Conference on Metadata and Semantics Research (Metadata and Semantics Research Conference, 2017) has been consulted to identify the most important properties of metadata, and how metadata could be designed to be used in our project with the best possible practices within the industry.

The following categories of Metadata are considered as some of the primary areas of interest by MTSR, and therefore are relevant in our project as well:

- Typology of Metadata and Metadata Implementations
- Languages and Frameworks for Metadata Management
- Case Studies
- Metadata and Ontologies in Education
- Search Engines, Localization & Visualization
- Digital Libraries, Big Data and Information Retrieval
- Information Visualization
- Metadata Quality
- Digital Curation

With brief research into these categories through MTSR’s research portal, I’ve conducted a proposal for metadata which has been documented in Appendix B 11.3

2.4 Argument for Traditional Books

We can see a tendency where technology is trying to replace physical books; too many solutions are proposed that would trade books for perceived convenience. The public is unconvinced, however, that eBooks can replace regular books entirely (Alison Flood, 2018). Perhaps we have become so polarized by technology that having an actual book, instead of a version of it on an iPad, is the more meaningful and embodied interaction (Tervalon, 2015).

Furthermore, we can observe the benefits of traditional books for the psychological development (Hom, 2016) of children (or more precisely: the detrimental effects of glass/screen-based devices (Baron N. S., 2015)). Traditional books also support more focused and enabled reading, for both academic and leisure purposes, especially because of ergonomics (i.e. digital screens being eye-straining and often difficult to read in bright conditions / in sunlight)

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1 OCR stands for Optical Character Recognition, and may be used to recognize which book is being read
2 RFID stands for Radio-Frequency Identification. It’s a barcode/sticker used tag books electronically
Finally, my personal opposition to the glass interfaces that have thoroughly entangled the modern world: an argument for not using glass, if possible. This notion was pointed out in “A Brief Rant about the future of Interaction Design” (Victor, 2011), where the author lays a claim to the better utilisation of the somatosensory system and criticizes the use of glass in the design of input devices. The author calls for “a dynamic medium that we can see, feel, and manipulate”, an ambitious, long-range vision where he also says that “Pictures Under Glass is old news”. This provides motivation for SAR-reading, as sensors and cameras may track interactions of tangible objects such as the book. In addition, support for a sense of touch is provided in the IEEE Multimedia journal (Robles De La Torre, 2006)

This is to say that the Mixed Reality Book is an attempt at a technology that is parallel to the existence of a traditional book. It does not replace them; nor should it. Without the traditional book mediums, this technology loses a clear majority of its embodied feeling, so it should not exist as a standalone reading framework (although this notion may be challenged as the technology is researched).

2.5 Forms of Interactivity

At a concept, I envision the interactivity of this system to be intuitive; the augmented content would appear depending on what page is opened in the book. The simplicity of this basic interaction would mean that the user would be immediately familiar with the affordance of changing the pages that would reflect the change digitally. However, I intend to explore the role of artefacts and affordances in the books, as well as outside of them, elements that would enable meaningful and practical interaction. We will be exploring hand and pen-based interaction and identifying the most valuable forms of interactivity that could be further developed to design and test interfaces for Mixed Reality reading.

2.6 Canonical examples

This section contains a body of state-of-the-art technologies and research that were used to develop the Mixed Reality Book concept. A definition, intention, and purpose of this technology is described in this section, as well as a reflection on how this work fits together.

2.6.1 Spatial Augmented Reality

Spatial augmented reality (SAR) is a technology that can manipulate real world artefacts and environments (Ramesh Raskar, 2005). Requiring no additional wearable hardware, head-mounted glasses, or external display, it uses projection technology to overlay and mediate digital content in the real world. Because it is usually an environment co-located solution, SAR enables a viewing range for multiple users, allowing collaboration within its projection area. The choice for SAR was made because of its capacity to shape an environment without additional hardware.

Examples of SAR may include shader lamps, pico-projectors, and short-throw projectors which can be used to create virtual tables – a concept that is valuable in the context of this project. SAR also requires certain technologies, such as Projection Mapping and Sensors, to be able to manipulate the environment in a dynamic way. Because of the advancements in this technology, SAR systems can display content on a vast range of surfaces and materials, in environments ranging from dimly-lit indoor rooms to outdoors.

2.6.2 Projection Mapping

Projection mapping is a methodology in Spatial Augmented Reality that uses a combination of sensors and projection technology to turn objects and artefacts into a display surface for graphical projection (Jones, 2015). These objects may be irregularly shaped with different materials, located at different places within the environment. Using sensors such as the Microsoft Kinect, a depth map and 3D representation of surfaces can be created, which allows digital processing to create textures and projection areas. This method is widely used to project extra dimensions, optical illusions, and notion of movement – for example, on the facade of buildings. Projection Mapping is useful in the context of the Mixed Reality Book, as the artefact we will be working with is irregularly shaped and requires deeper consideration for its texture mapping.
2.6.3 Short-throw Projector Technology

Short-throw projectors are increasingly becoming more common, especially within educational institutions. A conventional digital projector is an optical device that uses a bright light that shines through a matrix of pixels to focus and produce an image onto a surface or projection screen. Because of the optical properties of conventional projection, the device needs to be situated far from the projection surface, often requiring to be placed meters apart. Projectors with short-throw technology are being used in this project as they use different optics and mirrors to focus the picture (Figure 3). The Sony Xperia Touch (Martin, 2017) is a projector that is very close to what is being conceptualized in our project, as it even includes a tracking and multitouch system.

![Figure 3 – Comparison of distance in projectors](image)

2.6.4 Kinect

The Kinect is a multi-feature sensor device produced by Microsoft. It features a depth sensor, a multi-array microphone, and an RGB camera to capture motion, movement, and 3D capture (Microsoft, 2009). This device, although originally developed for gaming with the Microsoft Xbox, is widely used for prototyping within the Interaction Design community, and has a large array of applications and uses, especially in the context of tangible interaction (Caltenco & Larsen, 2012).

It’s important to note, however, that the technology utilizing Microsoft Kinect has been discontinued as of March 2018, which has created obstacles due to outmoded software frameworks. A list of Kinect alternatives has been detailed in Appendix B 11.4.

2.6.5 Existing SAR/Projection Research

A great deal of information was discovered regarding using projector technology in augmenting content and books. For example, Pinhanez et al considers an “Everywhere Projector” (Pinhanez, n.d.) that could be used to display graphical interfaces on any surface. We can also encounter earlier Augmented Reality work dating back 24 years, where a class of Mixed Reality displays is presented and analysed (Milgram, 1994). I identified, in my opinion, the most relevant advancements that would help us with our concept:

Relevant 1: Projector/Camera Addition

Perhaps the most significant document I would like to draw attention to is the “An information addition system on books using a projector-camera” (Yoshida, Yamazoe, & Lee, 2017).

This document proposes an information addition system onto books by using a projector-camera system. This paper was discovered after a rudimentary prototype had been made and helped highlight some of the challenges in the hardware area I have faced myself. The paper seems to predominantly focus on the HCI element of the prototype, and describes how the researchers have built one, with suggestions on how certain technical and software barriers can be solved. I used their suggestions for the projector position and angling in my project.

This is to say that our prototype is not entirely dissimilar, but uses different types of technology, and aims to focus on Interaction Design rather than HCI/Industrial Design.
Relevant 2: Microsoft Illumiroom

A great source of inspiration was Microsoft’s Illumiroom concept (Jones, Benko, Ofek, & Wilson, 2013), which is designed to create peripheral effects on your living room wall, where the TV/Home Theatre is (Figure 4). Using Microsoft Kinect, the room is 3D scanned and projected over to enhance gaming experiences.

![Figure 4: Microsoft IllumiRoom](image)

This research has been very important to the development of the Mixed Reality Book concept, as it shares some very common elements, including both the technology and the theory. Where Microsoft’s technology aims to enhance the experience of TV and gaming, we aim to enhance that experience for books; this presents different challenges for both, as the objectives, requirements, and output can be vastly different.

Especially useful were the research and references conducted to create this project, because they provided a very thorough and informative analysis of the implications of Spatial Augmented Reality, and directed to the state-of-the-art canonical examples that this technology employed: MirageTable (Benko, Jota, & Wilson, 2012) is one of those examples that discusses the affordances and interfaces on a virtual table. Additionally, conventions of artwork superimposition are considered and analysed in further references (Bimber et al., 2005).

Relevant 3: DataTiles Interaction

Interesting research was conducted by a team of scientists at Interaction Laboratory of Sony Computer Science. Although the paper dates from 2001, its research is still relevant today, as it outlines a foundation for mixed physical and graphical interactions, which are missing from today’s glass interfaces.

The DataTiles system (Rekimoto, Ullmer, & Oba, 2001) integrates the benefits of two major interaction paradigms: graphical and physical UIs. These tiles demonstrate a tight coupling of input and output, through tagged and transparent objects; for example, how data can be projected on glass. Unmistakably, the paper references 2001: A Space Odyssey, where glass interfaces can be observed. In fact, in one of the Mixed Reality Book studies a glass table (11.2.6) is employed as a control surface for a projected 3D object underneath.

Relevant 4: Electrolibrary

Electrolibrary is a Paper book as an input device that allows one to control a computer via USB using a regular paper book (Waldek Węgrzyn, 2016). This concept is important for Mixed Reality Book because a major technical challenge was detecting when a page is flipped. Unfortunately, Węgrzyn’s concept required sensors to be soldered onto every page of the book, which, in this author’s opinion, creates an impossibly difficult challenge of having a custom-made book where the pages no longer feel like paper because of metallic conductive paint elements built into them. However, despite that, the concept is very interesting and provided some valuable insight into how book page numbers can be tied to digital content (11.5). An alternative way to detect page flipping and potentially page numbers, that do not require intervention or modification of the book, was developed during this project. This is described in the hardware section in the Appendix B.
Relevant 5: FingerLink

FingerLink is codename for a prototype system, developed by Fujitsu Technologies, that can connect any paper book with a digital computer environment (Yirka & Laboratories, 2013). In fact, it can be any physical object or surface.

![Figure 5: FingerLink use scenario](image)

Presented for the first time in August 2013, the concept detects objects your finger is touching in the real world. That way, the surface you touch becomes a touchscreen interface (Figure 5). This makes the physical book practically a touchscreen surface where notes and definitions can be made, as well as inquiries for searching and notation. This concept is considered in the Sketching study, where children can draw in the book and save its content; it is also relevant in text highlighting later.

Relevant 6: Elektromeier Augmented Reality Book

Developed by Elektromeier Media, this project shares a similar vein to what the Mixed Reality Book is being developed towards (Elektromeier, 2017). The prototype shows novel capacities of adjoining a traditional book with digital media: showcasing Projection Mapping, Motion Tracking and papermechanical effects (Figure 5A) that are used to control elements of the book. Although this prototype has been discovered in the concluding stages of this project, it further motivated the notion behind the use of Mixed Reality with paper books. It shows a clear and concise technical implementation of its features and aesthetics. The difference, however, is that Elektomeier focuses particularly on using blank pages, a concept that has been briefly explored in this project (11.2.2), but later evolving into more pragmatic “outside-the-book” periphery.

![Figure 5A: A papermechanical slider is used to control the chart in the book](image)

Combination

A mix of these technologies have been used to create the Device Prototype outlined in the design process section. This device utilizes elements described here to create immersive peripheral effects and interaction experiences. Each project was analysed (10.4.3), and its strength and weakness considered and compared to our solution. While many existing concepts offered inspiration for ideas, their implementation did not always align with the desired experience of this project, which is why alternative technologies, software, interfaces, and input methods were used to achieve the result.
3. METHOD

3.1 Project plan

The project had been planned very carefully using the Gantt project management system (10.4.1), with milestones and deliverables clearly identified. Originally, a variation of the Double Diamond (Davies & Wilson, 2013) was to be used to define a strategy and execute a solution. Upon reflection, it became clear that it was not possible to strictly adhere neither to the project plan, nor to the Double Diamond, because as concepts were being developed and tested, new design openings emerged which were interesting to explore. Building on the methodology of the Strong Concepts criteria, the best concepts were carried over to further studies. The process became countlessly iterative; the notion of “drifting” (Krogh, Markussen, & Louise, 2015) became apparent as design work became acquired the research through design. In fact, at one point I needed to stop myself from pushing these ideas further because of time considerations, stabilize and refine the Strongest Concepts (outlined in the Theory section), and instead include them as a section (11.2) in this report that may serve as a source of inspiration for both my own future ideas and for other interaction designers in the future.

An important element of the planning was to preclude documentation methodology, as well as consistent and constant weekly supervisions. This provided a sustainable structure and the much-needed pressure to continue at a similar pace throughout. The supervisions and their reflections were instrumental to the refining and the documentation of the project.

3.2 Ethical Considerations

During the development of this project, an array of people (teachers, parents, children, authors, students) were involved in sharing their feedback about the concept and interaction experiences. To preserve the integrity of the research, I have carefully observed the following elements of ethics.

<table>
<thead>
<tr>
<th>Voluntary Participation</th>
<th>Confidentiality</th>
<th>Harm</th>
</tr>
</thead>
<tbody>
<tr>
<td>The participants in the feedback and workshop have done so voluntarily and without coercion and were not pressured to voice their opinion or ideas. Written permission was given by the local library to conduct the workshop.</td>
<td>Identifying information has been omitted and anonymity provided to the participants. Additionally, the faces of children were blurred out after negotiating with the library staff regarding the use of pictures.</td>
<td>The heavy hardware has been secured with industry standard safeguards, and no harm, physical or psychological, has been inflicted during evaluations.</td>
</tr>
</tbody>
</table>

**Table 2. Elements of Ethics**

<table>
<thead>
<tr>
<th>Informed Consent</th>
<th>Restricted Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>The participants were told about the purpose of the evaluation and how their information might be used in research</td>
<td>Considerations for content have been made for the children’s workshop, and horror themes have been omitted and replaced with more child-friendly themes.</td>
</tr>
</tbody>
</table>

3.3 Methods Used

3.3.1 Fieldwork

During the late exploration phases of the project, I utilized methods to conduct research on the reading process at home and in the library. Some of these methods were enabled after the construction of the initial prototype. These included Shadowing and Contextual inquiries, as well as Interviews. General observations on reading at the library have been conducted, which opened a design space for Ergonomic Considerations.

3.3.2 Prototyping & Hardware Sketching

Perhaps the most significant portion of time during the exploration phase was spent on sketching various Hardware prototypes, using a Projector, a ThinkPad notebook, and Arduino with a sensor kit. This was very important to identify the possibilities and capabilities of the hardware that was available at the time. A "Living
Lab” (Pallot, 2009) approach was used where the hardware was installed in an office, and a library where users and potential stakeholders could interact with it (11.1). Identifying a working hardware concept was crucial to start experimenting with content, even if not all features were enabled at the time of testing. To compensate for the lack of interactivity features, methods such as Wizard of Oz (Hанington & Martin, 2012) were employed. Considerations for developing theorized interactivity are also detailed in the Hardware Prototype section in the Appendix B. The prototyping process, both software and hardware, is heavily influenced by “What do Prototypes Prototype?” (Houde & Hill, 1997), where we focus on the role of the artefact in a use situation, its look and feel, and implementation. The process is additionally facilitated by Design Engagement Templates, which detail the focus of prototypes. Moreover, experimentation with Arduino to develop sensors and the Microsoft Kinect to develop projection mapping has shown promise and allowed to integrate prototypes early on in this project. The rapid prototyping of hardware was not without its challenges, however; this is described further in the Challenges (6.3) section.

3.3.3 Strong Concepts

Throughout the development of this project, I used a method of intermediate design knowledge production called “Strong Concepts” (Höök & Löwgren, 2012). The properties of it include being generative and carrying a core design idea, cutting across use situations and even application domains, being concerned with interactive behaviour rather than static appearance, relying on behaviour over time, and residing on an abstraction level above this instance.

The use of Strong Concepts is observed during the iterative “mini-studies” conducted independently from each other as well; each study had a specific artefact or affordance that would be tested, but in doing so, connections were made that would often leap, not only outside the study, but even the context of the project. A collection of such leaps contributed to the development of this concept for academic use, as showcased in the second workshop. Even in the workshops, strong concepts were often identified and analysed: the identification of an entirely new context and branch for this project; analytical/telemetric viewing with tangible heatmaps; a product of social navigation to be. Additionally, seamfulness (Höök & Löwgren, 2012) is a predominant concept throughout our interplay with artefacts, especially when drawing distinctions between artefacts and periphery.

3.3.4 Wizard of Oz

In some part, design research experiments in which the users interacted with the Mixed Reality Book were substituted with manually activated switches. The switches were activated using a remote control in such a way that it would be unseen by the participants. This created a perception that the interface and system is autonomous, which was important in conducting the interactions.

A mix of functional and semi-functional interactions was employed alongside Wizard of Oz. This exercise was important in the iterative design approach, especially in the early developments of the prototype, where Multitouch functionality was unavailable.

3.3.5 Collaboration with Stakeholders

As the project was being developed, every new concept and idea was shared with my associates, friends, and dedicated stakeholders. I have received and documented feedback about the initial concepts which have proven to be a catalyst point for further ideas and further feedback. An emphasis was made on exposing this project to relevant experts and, in our case, library staff, authors, illustrators, teachers, parents, and students.

Structured and semi-structured activities were planned to expose the concept to a wide range of users in an authentic way. The first major workshop was conducted in a library, where the system was installed, and several demos shown to children, parents, and book illustrators alike. This workshop has proven to be an invaluable source of feedback and inspiration and changed the course and emphasis of this project, as well as the design of the prototype. This is detailed and analysed in the Workshops (4.3) section of this report.

The second workshop used the findings of the first one to narrow down on the valuable elements, fleshing out the concept for an academic environment in a different context. Strong Concepts have been identified to narrow down the possible interactions.
3.4 System Architecture

A brief mock-up of the system architecture has been prepared to illustrate the necessary technical conditions to create a prototype of the Mixed Reality Book. The following hardware, software, and environments have been identified as crucial for a rudimentary prototype:

<table>
<thead>
<tr>
<th>Hardware</th>
<th>Software</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lenovo ThinkPad x220</td>
<td>Microsoft Windows</td>
<td>Internet Connection via WiFi</td>
</tr>
<tr>
<td>ELEPHAS CL760 Projector</td>
<td>Kinect SDK</td>
<td>Dimly lit environment</td>
</tr>
<tr>
<td>Microsoft Kinect v1</td>
<td>OpenFrameworks</td>
<td>Clear white surface at 60cm</td>
</tr>
<tr>
<td>RFID Reader</td>
<td>Visual Studio</td>
<td>Mountable Bookshelves or Light Fixtures</td>
</tr>
<tr>
<td>HDMI Cable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USB Cable</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The graphic below explains how these elements work together to create a mixed reality reading environment (Figure 6). The blue rectangle indicates the software. A more elaborate version of the System Architecture has retrospectively been created and added to Appendix B, along with further software and hardware considerations.

3.5 Documentation Methods

The documentation process was of utmost importance during all stages of this project. I decided to use a combination of multiple documentation procedures to ensure that important details are captured for later analysis and review. Here are the primary methods:

3.5.1 Video Journals (12.2)

For a project of this fidelity, video documentation was crucial to record working prototypes, concepts, and user interactions, as well as failures and hardware faults. This documentation proved especially useful towards the end of the project, where the research and working concepts could be shown to fellow students and researchers for a better understanding of what this project is. References with this icon (●) indicate a playable video. Additionally, a video out of all 10 “mini-studies” has been compiled and added to Appendix C.

3.5.2 Research Diary (10.1)

A table of chronological research has been compiled throughout the development of this project. Optimal and relevant findings often influenced design decisions and provided a great support point for the development of this concept and introduced new knowledge. The Research Diary can be found in the Appendix A section.

3.5.3 Weekly Reports

The reports contained a summary of the progress on the project – including new research diary findings, design decisions, analysis and general thoughts on the process. This documentation proved to be useful when writing the process report. Weekly Reports were a part of the supervision schedule.
3.5.4 Framing Design Engagements

A template for Design Engagements (Larsen, 2017) has been used to document user interactions with the prototype and sub-prototypes. (Figure 7) (10.2)

![Design Engagements Template](image)

**Figure 7.** Design Engagements Template is used to frame and situate our Rated experiments to understand what exactly was being analysed and focused on

3.5.5 Workshop Analysis

A methodological approach was taken in the conduction and analysis of the workshops. User feedback was documented using Audio in the second workshop, with semi-structured interviews and transcripts at the end. After the workshops, the content was transcribed and written down, and used in combination with user answers, previous research, and earlier feedback (then to be triangulated with each other) to determine Strong Concepts and sort them into interaction categories (10.4.3).

3.5.6 Design Evaluation Matrix

A Design Evaluation Matrix (Larsen, 2017) is used near the end of the report to briefly evaluate the concept (Figure 8)

<table>
<thead>
<tr>
<th>DESIGN EVALUATION MATRIX</th>
<th>WHY</th>
<th>WHAT</th>
<th>Manifested HOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novelty &amp; divergent thinking</td>
<td>Framing of field</td>
<td>Concept(s) especially aesthetics e.g. ‘poetics’ s experiences of ‘use’</td>
<td>‘Mediations’ excerpts</td>
</tr>
<tr>
<td>Thematic relevance i.e. related to your subset of ‘bodily engagement’ and concerns within IxD</td>
<td>Reframing &amp; thinking outside the box</td>
<td>design elements or their combinations</td>
<td>Selecting/combining/appropriating/using/making design artefacts</td>
</tr>
<tr>
<td>Grounding &amp; context sensitivity</td>
<td>including the clarity of your framing</td>
<td>Insights for IxD concerning interactions involving the body</td>
<td>A telling demo regarding bodily engagement</td>
</tr>
<tr>
<td></td>
<td>Mainly ‘grounding’ building on your design engagements</td>
<td>Fitting for actual ‘use’ and ‘use’ situation</td>
<td>Presentation is able to convey bodily experiences</td>
</tr>
</tbody>
</table>

![Design Evaluation Matrix Template](image)

**Figure 8.** Design Evaluation Matrix Template

4. DESIGN PROCESS

4.1 Conceptualization

Before beginning to identify the necessary hardware, several minimal concepts were explored and sketched. A Buxtonian (Buxton, 2007) low-investment approach was initially used to sketch with ambiguity, on both paper and in hardware, with an eye towards exploration. The peripheral reading device would rely on projection technology, so it was important to consider the possibilities on how it could be embedded onto the book.
Originally, the context of use included using the book in any position and angle, in almost any environment. This, however, may have been too ambitious a goal. Upon narrowing down, several concept ideas crossed my mind, which were promptly sketched. Three types of interaction placements were conceptualized throughout the discovery phase; here is a brief description of their ergonomics:

<table>
<thead>
<tr>
<th>In-Artefact</th>
<th>In-Environment</th>
<th>On-Body / Wearable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 9, left: this concept precluded the embedding of a small pico-projector and sensors into a portable reading light accessory. The idea was to project digitally controlled light and possibly content in the book. However, after trying out some body storming exercises on myself, I quickly observed that the device is clumsy/uncomfortable and would have a limited range of possibilities in this project.</td>
<td>Figure 9, middle: This device would require embedding a peripheral projector onto the ceiling or bookshelf of the environment where the reading process would happen. The limitation of this would mean that mixed reality reading would require a specific area for reading, which can influence the reading situations and contexts. A prototype has been later set up to test its fidelity 11.1.1.</td>
<td>Figure 9, right: A head-mounted projection would provide freedom of movement and work in most environments. Inspired from OmniTouch (Harrison, Benko, &amp; Wilson, 2011). A body storming exercise was conducted with a baseball cap with a projector mounted on top of it, which raised serious concerns regarding the ergonomics of the device. The wearable idea was further complicated because of the power and computing requirements.</td>
</tr>
</tbody>
</table>

After conceptualizing and bodystorming several design engagements, I determined to scrap the in-artefact and on-body use situations. It became apparent that neither the in-artefact nor the on-body were comfortable enough from an ergonomics point of view, or that they had the accommodation to support high-resolution projection systems and copious computing power required to process projection mapping. Instead, the focus would be put entirely on an in-environment SAR solution henceforth.

Table 5. Two in-environment solutions were considered in the more mature conceptualizations.

<table>
<thead>
<tr>
<th>Freestanding SAR Reading Lamp</th>
<th>Ceiling-mounted Peripheral Reading Projection System (PRPS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conceptualized based on existing reading lamps, this device could be installed in most places with sufficient ceiling height. A major advantage of this prototype would preclude its freestanding aspect and self-calibrating rotating mechanism that could create projected periphery in a large area.</td>
<td>This second concept became apparent after grounding the concept within the context of libraries. A freestanding solution would create difficulties in its installation and may be prone to breakage and vandalism. Instead, I considered a device that may attach itself to sufficiently secured ceiling lights or the ceiling.</td>
</tr>
<tr>
<td>See: Sketch in Appendix B 11.1.4</td>
<td>See: Sketch in Appendix B 11.1.5</td>
</tr>
</tbody>
</table>
4.2 Environments of Use

After developing a stationary but movable prototype, the next challenge was finding suitable environments for it to be installed in for testing. Initially, the concept revolved around living room use, but upon opening the design space it became clear that the tool provides other places as well. I mapped out some of the potential environments where the prototype could be tested:

<table>
<thead>
<tr>
<th>Location</th>
<th>Use description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Living Room</td>
<td>Recreational use within the living room: an exploration on how the reading experience could be enhanced reading fiction.</td>
<td>Available</td>
</tr>
<tr>
<td>Kitchen</td>
<td>Augmentation of recipe books with more visual step by step instructions and visual aid</td>
<td>Available</td>
</tr>
<tr>
<td>Home Office</td>
<td>A space on the writing table to enable mixed-use reading, work and research.</td>
<td>Unavailable</td>
</tr>
<tr>
<td>Public Library</td>
<td>A space allocated specifically for Mixed Reality Book experiences spanning all genres</td>
<td>Available</td>
</tr>
<tr>
<td>University Library</td>
<td>A space or an isolated room specifically tailored for use of peripheral reading in the consumption of academic literature</td>
<td>Available</td>
</tr>
<tr>
<td>Classroom</td>
<td>A matrix of projection systems concentrated on the student’s desks</td>
<td>Unavailable</td>
</tr>
<tr>
<td>Office</td>
<td>A room or a table dedicated to the consumption of reports and work documents</td>
<td>Unavailable</td>
</tr>
</tbody>
</table>

I chose to focus on the Public and University libraries as both institutions were easily available and offered several easily-accessible stakeholders. This went into the consideration of the design and theme of the Workshops. Permission to install the hardware was granted in advance of the sessions.

4.3 Workshops

4.3.1 Local Library

A unique opportunity presented itself after showcasing a rudimentary Mixed Reality Book prototype to the staff of a local library. They recommended to include a workshop in their Library Week program, the theme of which was “Building the future”. Libraries have historically been a nexus for innovation in book technology production and distribution, therefore, it seemed like a fitting time and place to try out the concept. Additionally, a presence of librarians, book authors, and illustrators during the event would contribute to the ideas and feedback.

This workshop would be focused primarily at children ages 9-11; on that day, most of the events would be designed as playful events. This influenced some of the studies I had been doing to prepare a test for a playful interactive experience in using the Mixed Reality Book.

4.3.1.1 The main objectives of the Workshop:

- Identify the positive and negative qualities of the Mixed Reality Book
- Gauge the engagement level of children
- Observe perceived affordances and interactions
- Collect opinions and reactions
- Discuss the process with the library staff and document their input and ideas
- Showcase the concept to a book illustrator to find out their opinion of the concept
To help design a workshop I consulted certain principles of participatory design, namely “Why design: labs?” (Binder, 2007). Some principles of these design negotiations were put into consideration when developing both the workshop and the prototype, as we’re aiming for participatory inquiry. For that, an area in the library will be reserved to create a space where testing will occur. Additionally, ideas for content was partially inspired by “Storytimes with an overhead projector” (Faurot., n.d.) Here are the main 3 activities that have been deployed:

<table>
<thead>
<tr>
<th>Cinematic</th>
<th>Audio</th>
<th>Sketching</th>
</tr>
</thead>
<tbody>
<tr>
<td>The first and most basic exercise was to let kids interact with the Cinematic book – a book specifically designed digitally to have interactive elements and effects that would be shown in the periphery (Figure 12)</td>
<td>This book augments the idea of the Cinematic experience and adds audiobook-style narration to the experience. The story has been recorded by my associate and embedded into the mixed media file</td>
<td>Last augmentation of the Cinematic book allows kids to use the book as a digital drawing canvas to express their emotions and creativity after reading each page (Figure 13)</td>
</tr>
</tbody>
</table>

These examples were thoroughly tested before being deployed to avoid any mishaps and account for limitations in technology. A small portion of the exercise was carried out using Wizard of Oz methodology because of the lack of multitouch interface at the time of the workshop.

It’s worth noting that the Sketching exercise idea (Figure 13) came about accidentally while I was making notes on the Mixed Reality Book’s test content; the idea to allow sketching within pages and allow content to be saved was something I did not originally plan, but decided to implement into the workshop anyway, based on the previous experiences of providing participatory design engagements in workshops. Additionally, I encountered several books when I was picking what book to use the story from; they seemed to have drawings in them, very likely from a member of the family that used to doodle (11.7) in the books while reading – some of the doodles were what appears to be a grading system for the characters that the child liked. This piece of psychology might be relevant, should our concept prove its worth.

### 4.3.1.3 Execution

The logistics for the digital hardware setup were provided by the library staff, including the transportation. The room where the activity was to take place was previously measured to account for height differences and the installation of the projection system.

Many of the library visitors took interest in the “lab” that was being set up. Before the workshop even began, some opinions and feedback were acquired as the children inquired about the nature of the device. They were quick to assume that it’s projection based, for example.

![Figure 12, 13. Cinematic and Sketching concepts (11.2.7)](image)

At the main event, all three of the planned activities were carried out, with the reactions of the visitors carefully documented during the process. It became clear from the very beginning that the unusual nature of the book attracted immense interest in both kids and adults; they all commented that they had never seen anything like this and enjoyed the experience of browsing a mixed reality book.
The second activity showed some surprise where the kids were visibly bored of the audiobook style text reading and preferred the visual effects of the cinematic experience. This finding casts doubt on the viability of using narration as part of the focused experience, seemingly because children were happy to take the book in at their own pace, without a structured or forced approach to timing. (this is also apparent during periods where the mixed reality book text appears letter by letter, locking readers into a specific pace that’s not always optimal to the target audience). This motivates trying an approach to organizing the media through interactivity, where children may request book sections and additional progressive disclosures.

![Figure 14: Sketching Exercise](image)

Lastly, the most interesting and engaging activity was the Mixed Reality Book sketching, where children could draw on an iPad, which would immediately translate the drawing activity onto the surface where the book is (Figure 14). This affordance seemed to have been very engaging, and it’s been rated as the most positive feature in the concept. It seemed that after reading a page of the book, a brief hiatus was needed where kids could draw a situation or a character from what they just read, providing a very embodied moment of creativity that seemed to have enriched the experience with the Mixed Reality Book. This kind of user experience could give children an opportunity to revisit their own personal memories and interpretations of the story, many years later after they had created them.

The technical setup for this sketch included a very basic HTML5 canvas application that was hosted on my server, with RESTful API that allowed one to mirror the website’s changes based on the session. This was done to get around the limitation of relying on 3rd party services which were not completely suitable for the context of this activity. Considerations for the software choices and alternatives are available in Appendix B.

Moreover, because of the light properties of the projector, a black background was chosen with a light brush, simulating a blackboard + chalk style effect, which would be familiar to children of this age and a more visually compelling experience. In a more fleshed-out version of the concept, screen mirroring would no longer be necessary; the sketching process could be done – with either a finger or a stylus – directly on the surface of both the book and its periphery.

![Figure 15 – Children interacting with the book](image)
4.3.1.4 Results & Feedback

Overall, the concept has been rated positively by children, staff and visitors alike (Figure 15), many of whom had suggestions and ideas on how this concept may be developed further.

I prepared a series of questions to the staff and the illustrator:

- What do you think about the potential of this technology?
- Do you consider it being useful or a distraction?
- What ideas do you have for the animations?
- Did you like the interactions?
- What responsibilities do you imagine having as a book illustrator when designing for this context?

The feedback and ideas are included in Appendix A (10.3), but to summarize: both the staff and the author considered this technology to be a good canvas to make books more interesting for the younger generation. They expressed concerns over the logistics of the technology (the size, lighting requirements, lack of certain features at the time of the demo). The Audio content has been rated negatively because of the forced timings and removed from the project for now. The interaction experience seemed to have been positive, and very embodied, which in the opinion of the library staff is a great point of engagement for children.

The illustrator had only a few minutes to leave comments, but said he enjoyed the experience, and sees a lot of potential in peripheral cinematic effects to create richer reading experiences. He also expressed concern over the technical requirements of producing this content digitally, and whether a framework (and training) could be provided that would allow animators design these experiences while using the projection (a developer mode is now considered), especially because certain elements of the mixed reality experience require programming and logic gates.

A particularly interesting design space was suggested by the staff of the library: using peripheral effects with Geography encyclopaedias and textbooks – and being able to project maps of countries and topographies in the periphery for a visual learning experience. This created the catalyst for the next workshop where metadata and additional information would be added into books.

4.3.2 Orkanen Library / Studio

The second and final workshop was designed with the findings of the first one in mind; I picked the most desirable attributes of the interaction: the peripheral holograms and the sketching exercise activity. However, the second workshop would target a different demographic: mainly students and teachers. The next Study of the prototype involves its use in academic environments: consumption of academic texts, literature, encyclopaedias, and more. We will be using the same hardware and software framework to see what value we can deliver using the Mixed Reality Book in this context.

The main objectives of the Workshop:

- Identify the positive and negative qualities of the Mixed Realty Book in an academic context
- Gauge the engagement level of students
- Observe perceived affordances and interactions and compare them to children’s
- Collect opinions, reactions and ideas
- Discuss the process with the students & library staff and document their input and ideas
- Showcase the concept to a teacher
- Compare the findings of the first and second workshop

3 Logic gates are a semantic of input-output programming. In this context they may afford changing conditions based on interaction, for example – if an interactive element is tapped with a finger, X must happen.
4.3.2.1 Planning of the Workshop

The plan for this workshop included body-storming with the students as well as elements of Wizard of Oz and semi-structured interviews and interventions during testing. I prepared 3 primary elements that I wanted to test with the students and teachers.

<table>
<thead>
<tr>
<th>Reference Viewer</th>
<th>Interactive Content</th>
<th>Annotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>This sequence allows one to highlight specific paragraphs of text and see the related definitions or references that the paragraph points to. Through this exercise, we want to see whether it’s a useful interface, what affordances make the most sense, and receive input on the styling.</td>
<td>Animated and Video content displayed alongside chapters of books, medical examples of movement. Several different ways to play the animation were presented; automatically, by moving the slider, or by tapping an icon.</td>
<td>Like the children’s sketching exercise, this activity intends to explore how annotation can be made in the academic context, what affordances enable it in a meaningful way, and what features are expected of it.</td>
</tr>
</tbody>
</table>

These examples were again thoroughly tested before being showcased as the prototype did not have the full fidelity of multitouch. The process was documented using Design Engagements (10.2). Moreover, other demos such as Accessibility and Telemetry were briefly showcased. It’s worth noting, that the workshop has been conducted in multiple stages throughout the day, with multiple students and professors. Certain design considerations have been rapidly prototyped and implemented back-to-back in each session.

4.3.2.2 Execution:
The second-generation prototype has been secured onto the light fixtures of the classroom (Figure 16). This has been done after identifying the loadbearing capacity of the fixtures to ensure no damage is done to the environment and that the prototype is safely secured.

A basic implementation of a semi-interactive Processing interface was prepared for the workshop where rudimentary interactions were possible through a combination of touch (using the Kinect) and Wizard of Oz (where interactions were not synchronized with reality).

![Figure 16. Compact Composite PRPS-02 Prototype at the Orkanen Building](image)

After the hardware and software was configured to its optimum performance, a few tests were run to ensure that it worked as expected. Participants arrived as scheduled and began interacting with the projected periphery shortly. An introduction was given to the nature of the technology, its possible applications, and the intentions of the workshop and its results. Consent was given to use pictures and record audio during the workshop.
4.3.2.3 Results & Feedback

All three design engagements were carried out with different students (Figure 17), making a point to document them on the fly. Because some of the participants were design students as well, a lot of feedback and constructive criticism was received that’s been considered in follow-up prototypes. In fact, small tweaks were made throughout the day as the workshop spanned that entire day and had different participants each time.

The following questions were asked, in a similar vein to the previous workshop:

- What do you think about the potential of this technology?
- Do you consider it being useful or a distraction while studying?
- What ideas do you have for features and interactivity?
- How do you interpret the design conventions of this prototype?
- Which challenges do you think would occur in the deployment of this project?

The participants were impressed with the capacity and design space that this project affords. A body of features (5.2) such as reference viewer, translator and annotation making and sharing system, were particularly well received. These features are discussed in the “Academic Features” section up next. Comments and concerns were made on the intuitiveness of the affordances presented in the prototype; the drag and drop interface, for example, was not immediately obvious (10.3).

Further concerns were raised regarding the design conventions of the prototype – namely an idea suggested by a student to specifically include blank pages for projectable content. A short debate followed amongst the participants and the idea was dismissed. The students preferred content that would be secondary to the book, without needing to remove any extra features. Additionally, negative perception was observed on a design probe which projected imagery over the text itself; it was described as “disorienting” (10.3).

Overall, the students considered the use scenario to be promising within the academic context, some of whom expressed the desire to already have this technology so that it could be used to help them with their studies; “This project appears to offer many of the benefits of using a laptop without the distractions [of the web]” (10.3). This was something I hadn’t considered in the design of the concept but is a very welcome accidental feature that could be explored and elaborated.

The last design engagement was briefly tested with a professor at Malmö University. The interactive content aspect was tweaked to accommodate the subject the participant specializes in, to better assess their perception of the usability context. A surprising (as we only focused on interaction semantics) yet obvious elaboration of the entire concept was suggested: an ability to tie in user accounts and expand library database features in form of a dashboard, as well as having metrics and statistics with transparent access to the students. These concepts are detailed more in the Academic Features section of the report, 5.2.
5. MAIN RESULTS AND FINAL DESIGNS

Upon completion of the second workshop, it became clear that the most practical and valuable applications of the periphery system reside in education. I identified the Strong Concepts that would be carried over into what is close to the final design of this prototype for now. Elaborating the results of the first workshop created an argument for reading and play, whilst the second workshop gave insight into the affordances and conventions that should be considered when designing a fully functioning prototype.

5.1 Analysis

Continuing with the path set by design experiments and informed by workshops, I have analysed all the perceived meaningful interactions and Strong Concepts, as well as ideas suggested by stakeholders. Design Engagement templates, interviews, and notes were collected on a whiteboard (10.4.3) to make sense of the data. I used mapping exercises to identify common interactions from both workshops to extrapolate design conventions which could be implemented in a third-generation prototype. The most important finding in the mapping exercise was the distinction between the artefact and the periphery (Seamfulness), where affordances should indicate which areas and elements can be interactive, and which cannot, as well as surfaces that can be projected on, and which should be ignored by the system (Spatial Organization).

<table>
<thead>
<tr>
<th>Table 9. Meaningful Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interaction in the Children's Workshop:</strong></td>
</tr>
<tr>
<td><strong>Interaction with Peripheral Holograms</strong></td>
</tr>
<tr>
<td>Touching the projected periphery and what actions it may afford such as changes and sound</td>
</tr>
<tr>
<td><strong>In-book Content/Text Projection</strong></td>
</tr>
<tr>
<td>Use of blank pages to project content and text</td>
</tr>
<tr>
<td><strong>Use of Page Flipping to control Peripheral Content</strong></td>
</tr>
<tr>
<td>Controlling the periphery visualizations via only page-flipping</td>
</tr>
<tr>
<td><strong>Illumination of Books for better focus</strong></td>
</tr>
<tr>
<td>Ergonomic consideration of light in a dark room to enhance reading concentration</td>
</tr>
<tr>
<td><strong>Projection Mapping considerations when the book is moved around</strong></td>
</tr>
<tr>
<td>Moving the book around but keeping the content inside of it</td>
</tr>
<tr>
<td><strong>Sketching and Doodling</strong></td>
</tr>
<tr>
<td>Expression of creativity using pen and touch input</td>
</tr>
<tr>
<td><strong>Responsive Design and spatial considerations for content placement</strong></td>
</tr>
<tr>
<td>Spatial organization considerations</td>
</tr>
<tr>
<td><strong>Accessibility Features for vision impairments</strong></td>
</tr>
<tr>
<td>Dashboard features such as zoom and pan for visually impaired</td>
</tr>
</tbody>
</table>

Additionally, a specialized framework for negative aspects of this technology has been distilled from the semi-structured interviews and comments. Some of them are highlighted in the Challenges (6.2) section of this document. A complete list of possible Interaction Categories was compiled into a table which can be found in the Classification section (5.3.1). This table was later supplemented with Interaction Insights and distilled into an interactive and editable UX Map, which may serve as a template for the continued design of the concept.
5.2 Academic Features

These features are a combination of concepts tested during the second workshop and new concepts rapidly prototyped during the breaks between. Unfortunately, because of the time limitations of the project, these were not explored sufficiently, but exist as feature suggestions with rudimentary prototypes deployed alongside the core concepts of this project. I decided to include a brief description of each to better illustrate the potential of this project both in a technical sense and in a design space sense.

5.2.1 Dashboard / User Accounts

A semantic to consider in the more thorough design of the system architecture precludes the Dashboard Interface which allows Students to be log in using their Multicards (or equivalent). This would allow an extension of feature-set, such as the ability to log statistics, save blocks of text and references, access the databases of the library, and provide a more personalized experience. A mock-up of the Dashboard concept has been made with a very rudimentary UX map on how it might work (Figure 18) [AC2.11].

Figure 18. Student Dashboard Interface (The placement of the Multicard activates this interface)

5.2.2 Academic Report Viewer

This sequence would allow consumption of academic reports, much like this current document, in a more immersive and augmented capacity. As the report is consumed, the system could automatically preload references from the end of the document and display them on a contextual level within the periphery of the report (via a university-provided subscription service to research documents / backend). As suggested by one of the professors, this could be used as a powerful tool to evaluate the references by instantly loading them next to the real paper itself, a utility for both professors and students alike. Moreover, in combination with the dashboard features, this could be used to identify and save references while conducting research. (Figure 19) [AC2.11]

Figure 19. Academic Reading Interface (11.2.9)
Highlighting [► AC2.11]

This sequence allows one to highlight text and paragraphs within the physical book or document. The action may be performed in a couple of ways – with text that contains metadata-enabled affordances, such as references to a text or media of interest, or in a static way where the content does not specifically have any links. Tapping the activated text would bring up an interface that would display text or media related to it. Tapping and holding activated, or any regular text will bring up a contextual menu that allows the following features: Define, Translate, Share. Depending on the amount of text selected, the “Define” function may not be available. These affordances are very similar to text selection affordances on multitouch devices such as smartphones and tablets.

Our stakeholders found some these affordances (such as colour bars next to the text) to be immediately obvious and concise, without needing to have explanations on how to activate them (except that the features were not enabled yet and only exist as a demonstration device, and the drag&drop sequences).

5.2.3 Telemetry Mode

Statistical collection has been overlooked as a part of the concept in our project, but upon further reflection it became apparent that it could be a powerful tool which may give analytical information at the hands of the reader. Our concept briefly touches on the use of “Telemetry”; using the Microsoft Kinect, or a high-resolution webcam to identify unique pages and record the time spent by the reader on those pages⁴. A basic heat map may be generated from this sequence; with a sufficient sample size, it could be used to display on the page which pages are “hot” and which are generally ignored. A colour sequence ranging from red to dark blue would illuminate the pages accordingly and provide both students and professors with a potentially new way to identify which material has either deemed to be important by other students, or generally overlooked (Figure 20).

Figure 20. Heatmap based page illumination in Statistics mode

5.2.4 Accessibility Features

The fourth and final extended feature probe is tailored to the Accessibility side of the project. Although several medical contexts were considered earlier, an obvious use case for vision impairment and dyslexia has been conceptualized. This sequence allows the use of the Mixed Reality Book surface to drastically zoom any library book or document for easier consumption. A touch-based interface allows one to pan and zoom the segments of the text (Figure 21.). Additionally, the possibility to load a digitally enhanced variation of the document is considered when available: this mode would allow even more extended Accessibility Features, such as the capacity to change the font to a dyslexic-friendly character set, and an ability to use Text to Speech and translation features. Stakeholders noted the capacity in which this can enable consumption of regular books for people with disabilities. Further reading was conducted on understanding the visual perception and what difficulties may be encountered both in paper and digital reading. These examples are closely analysed in “Im Auge des Lesers” (translation: In the eye of the reader) (Hunziker, 2006)

---

⁴ Observing reading may carry Privacy and Data Protection implications that are not a part of this report
5.3 Possible Interaction Categories

To classify and categorize our design engagements, the following table contains all the possible interaction categories that were explored using the Mixed Reality Book. This is an important design consideration for the project, as our workshops identified elements where a distinction must be made between the periphery and the content. The periphery is detailed in the “Outside the book” interactions and contains the bulk of the Mixed Reality Book content. The primary interfaces only exist outside the book as we cannot project menus and additional overlays onto the book itself due to the diverse types of content that physical books may contain.

5.3.1 Classification:

<table>
<thead>
<tr>
<th>Interaction Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projecting Text inside a blank book</td>
<td>This sequence allows use of a completely blank book, or book with blank pages to create virtual content within it to simulate the experience of a real book.</td>
</tr>
<tr>
<td>Projecting effects and mixed media inside a blank book</td>
<td>Content that’s specifically designed to be within the confines of the book, including text highlighting, analytics and misc. overlays with the assumption that the book is blank.</td>
</tr>
<tr>
<td>Projecting effects inside a regular book</td>
<td>Same thing as above, only the assumption that the book has printed text and illustrations in it – upon which case certain limitations of what kind of content can exist with the book have to be imposed.</td>
</tr>
<tr>
<td>Periphery effects outside a blank book</td>
<td>Illustrations, Videos, Applications, Text and other media including Menus and GUIs that can be on the table, but outside of the book, with the implication that it’s blank.</td>
</tr>
<tr>
<td>Periphery effects outside a regular book</td>
<td>Same thing but the book is not blank.</td>
</tr>
<tr>
<td>Soundscapes with blank books</td>
<td>Audio content alongside blank books.</td>
</tr>
<tr>
<td>Soundscapes with regular books</td>
<td>Same thing but with regular text books.</td>
</tr>
<tr>
<td>Page flipping</td>
<td>Hand interaction in the context of changing the pages of the book.</td>
</tr>
<tr>
<td>Book / Artefact Positioning</td>
<td>Positioning of the book and artefacts within the periphery.</td>
</tr>
<tr>
<td>Multitouch Control</td>
<td>Use of multitouch to augment features such as text selection, highlighting, annotation and swiping.</td>
</tr>
<tr>
<td>Gesture Control</td>
<td>Theorized alternative to multitouch where gestures can be used to activate certain features of the periphery.</td>
</tr>
<tr>
<td>Artefact-based Control</td>
<td>A theorized alternative to gesture and multitouch where an artefact is used such as a pen.</td>
</tr>
<tr>
<td>Content Creation inside and outside the book</td>
<td>Theorized interactive editor for designers to create content.</td>
</tr>
<tr>
<td>Interaction with the peripheral elements</td>
<td>Use of alternative artefacts in addition to books in the periphery.</td>
</tr>
</tbody>
</table>

In addition to that, basing on the observations of the Workshops, I prepared several design recommendations that should be kept in mind when designing periphery experiences.
5.3.2 **Insights on Gesture Based Interactions**

- The system should be able to track multi-user inputs
- Conventional multitouch gestures such as scrolling, pinching and panning should be observed
- Tapping to hold should bring up menus
- Changing pages in regular books and media should be as natural as possible from a systems perspective
- Removing the book from the table should pause the peripheral experience for that book

5.3.3 **Insights on Social Interaction Dynamics**

- Projected Periphery should be aware of multiple persons at the table
- Momentum-based sharing could be used to “push” content to another user
- Notation by different users should be indicated in the system via different colours
- Moving to a different side of the table should rotate the periphery to the point of view of the user and the book
- In the case when there’s more than one person consuming the text, options should be provided to enable rotation

5.3.4 **Insights on the Spatial Organization of Content**

- Imagery should never cover or overlap the printed text
- When a book has moved on the table, the peripheral content needs to adapt
- When other books or documents are added to the table, content needs to fade out or signify uncovered areas
- If other elements are detected on the table such as smartphones, pens, etc., the content needs to move out of the way
- Menus cannot be overlaid over text
- Menus can be overlaid on illustrations

5.3.5 **Insights on Visual Aesthetics and Experience**

- GUI elements are best shown outside of the book’s confines
- Re-placing the book in another spot should re-calibrate the position of the interface
- In the case of a circular table, periphery may enter a circular orientation mode where periphery is based on the perspective of the book
- Dynamic media should include controls to pause and rewind content

This is only a preliminary list of recommendations as the concept has not yet been fully explored. I can foresee a documentation library with design conventions for Mixed Reality. Further categories may be explored, such as the addition of learning artefacts, for example – identifying Arduino components and using the periphery to show instructions and schematics. However, because this creates an identity crisis for our Mixed Reality Book (at this point, the need for a physical book is questioned), we will not continue considering further artefacts in the periphery. In an alternative or parallel project, a design space can be opened where the books (or any other item) can be represented using other forms of artefacts such as AR Markers.

In addition to the features described in this section, I decided to prepare a UX diagram which maps out the possible interactions with this system (Figure 22). This diagram can be used as a helpful framework in further designing the system architecture and the interactions. The diagram is broken down into two main areas: System Actions and User Interactions. The User Interactions branch contains semantics which were previously identified as Strong Concepts and implemented later in the design process.

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5 Augmented Reality Markers are commonly used to indicate where a digital object should be physically
I can see this diagram evolving further when more Strong Concepts are identified through testing, but because of the limited time and the two workshops, this project has only gotten thus far.

6. EVALUATION/DISCUSSION

6.1 Evaluation

An important outcome of this project is the critical outlook on its design and features. In this section, a Design Evaluation Matrix is used to overview the framing, concept, and mediations against its novelty, thematic relevance, and grounding. This evaluation is a preliminary self-critical juncture point after our second workshop.

<table>
<thead>
<tr>
<th>Table 11. Design Evaluation Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Framing of field</strong></td>
</tr>
<tr>
<td><strong>Novelty &amp; divergent thinking</strong></td>
</tr>
<tr>
<td><strong>Thematic Relevance</strong></td>
</tr>
<tr>
<td><strong>Grounding &amp; Context Sensitivity</strong></td>
</tr>
</tbody>
</table>

There have been some issues with the (re)framing of the research question, because initially it felt more like an engineering / HCI challenge rather than an Interaction Design challenge. The doubts about this rift were diminished upon entering the workshop phase where we tested live and moving interactions to get a feel for what worked and what did not. Using a “Living Lab” and the Strong Concepts methodology provided a good basis for the constantly ideating process. We identified the best interactions which were carried over back to back into what is currently the most fleshed out concept. Upon reflection, it’s evident that this project could have moved a
lot faster if we had engaged in workshops at much earlier stages of the process, instead of spending too much time churning out “mini-studies” and rapid prototyping experiments. The role of prototypes, however, should not be diminished as the Research through Design was a crucial component in my work.

All the stakeholders that have seen the prototype so far have been pleasantly surprised by its fidelity and capacity to make books come alive. The design ambiguity of the concept (both intentional and not) was sufficient to give stakeholders a chance to be both critical and constructive; upon reflection, many of the best ideas had not even crossed my mind. The design engagements and the “Living Lab” approach provided space for others to not only participate in the co-creation of this concept, but also in a rehearsal for the future (Halse, Brandt, Clark, & Binder, 2010). This is the essence of meaningful design: to be sensitive and perceptive to the thoughts and feelings of other people, and facilitate user-driven innovation when designing tomorrow’s products. I see no other way this project can continue to be designed if not through collaboration.

It’s difficult to say at which point this concept exists now, considering a range from Buxtonian post-it sketches, to a fully functioning market-ready prototype, a great deal of work is still required. Ensuring that the Mixed Reality Book not only works from a technical perspective but is a meaningful experience for its users. We identified some qualities of this experience through our research, but many things remain unidentified still, which is why I consider this project more of a foundation for things to come. A large section of the Appendix B is dedicated to considering the logistics and semantics that could help make this project a reality.

6.2 Social Challenges

The biggest challenge in this project, of course, was finding people to work with. I have been very lucky to have captured the interest of the local library by demonstrating the initial concept. This required some effort on my part, including being able to present and pitch the idea, as well as being able to conduct myself in a professional and academic matter to convince the library staff of its merits.

The library workshop’s stakeholders were not ideal by the fact that they were children; this created difficulties in being able to document their reactions, comments and behaviours, especially because filming was not allowed and required express permission from the parents. Moreover, almost every participant had a comment or a feature suggestion for the system, which created a danger of Feature Creep. The project does in fact suffer from this because of receiving so much feedback and many suggestions.

Finally, here is an observation made by a visitor during the first workshop worth mentioning. “It appears that this (peripheral) reading may be a substitute for children’s imagination”. This concern seems to be valid; however, it was rebutted by the fact that many children’s books already have illustrations and they are preferred by the children because of that. The question whether periphery illustrations can impede imagination while reading is a matter for the illustrators themselves, as these can be made as detailed or as ambiguous as needed. It is not certain, however, to what extend peripheral illustrations may affect children’s ability to concentrate and focus. Further research may need to be done to determine that.

6.3 Technical / Pragmatic Challenges

6.3.1 Multitouch

This One-Kinect multitouch interface has been shown to not be entirely reliable, especially within the drag and drop context of the text. This is a consequence of outmoded software and certain ergonomics such as the book being at a slightly different height than the table. Because of this challenge, I considered a Two-Kinect solution and conducted a brief experiment with it at a late stage of the process, after the workshops were done. It seems that adding more Kinects can dramatically improve the sensory aspect of the interface and should be considered in the further development of the project.

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6 The tendency of a design project or product cycle to accumulate more and more features or details, rather than to be completed and released at a more basic level. (yourdictionary.com)
6.3.2 Cooling Issues

Another major issue that has been identified during the early design engagements was the cooling / noise of the projector. The prototype projector I was working with did not have adequate cooling and fan ergonomics, which resulted in approximately 28 dB of noise. This level of noise is unacceptable in most environments and stands as a major hurdle. Brief research into available technology suggests that more expensive projection systems reduce this problem dramatically. A water-cooled system is proposed in the 3rd Generation Prototype in Appendix B.

6.3.3 Co-location

This technical limitation draws on the stationary nature of the projection system; only a limited area, for instance a table or several square meters of floor, can be active. This demands that the entire reading experience be co-located with the projection system; and in our case, it is difficult to even move the book up from the table as the optics of the projection need to be re-calibrated mechanically (11.1.1).

6.3.4 Content Creation

The most common question that the stakeholders asked was, where does it get the content from? While the Wizard of Oz prototype precluded built-in and scripted content, this raised a lot of concern about the viability of the concept. Some features, such as translation and accessibility, may work without any specific tailoring; most books would require content to be designed for them. This creates a chicken or the egg problem for Mixed Reality Book – for the content to be created, we need to have this prototype deployed in certain locations (Developer Mode – Appendix B 11.9). And yet, for the prototype to be deployed we need some bare minimums of content that can be consumed already. It’s this author’s opinion that a library of several books would need to be converted for digital periphery, before installing a prototype. Re-authoring, re-illustrating and designing interaction for books are likely tasks for authors, illustrators and interaction designers in the future.

6.4 Method Reflections

Throughout this project we engaged in several different Methods, which seemed to have collectively worked together to produce tangible results. The most important methods included Hardware Sketching, User Testing, and Workshops, the last two serving as the foundation and core of our data collection. The quality of the interaction evaluations was situated in the capacity of our stakeholders to be honest and reflect upon the questions during the testing process. In the case of the first workshop, as mentioned previously, it was difficult to have a structured approach to gauging the children’s engagements; instead I focused on noting down their reactions and interactions with the interface, with questions in between. The much more valuable feedback came from the library staff, who observed the workshop, and had very interesting reflections and suggestions for the project. This is to say that the presence of library staff has improved the quality of the results. The continued second workshop was designed with these experiences in mind, and facilitated a more conductive engagement process with the students, affording valuable feedback and suggestions. The input of a professor was also important because it became clear how this project could be used as a powerful academic tool.

On the matter of prototyping: the hardware sketching seemed to have been crucial in identifying the initial experiences, as well as coming up with engaged and situated interactions through Strong Concepts. Wizard of Oz provided great facilitation where technical and software limitations would have slowed down the project and made certain interactions outright impossible (within the given timeframe). My primary concern regarding prototyping was the fact that a larger amount of time was spent figuring out the inner workings, aesthetics, and logistics of the project, which, upon reflection, is not as important as identifying meaningful interactions.

Lastly, the project plan and the time frame of our tests and workshops has undergone a tremendous transformation. What was supposed to be a rigid Double Diamond approach became an iterative process. The decision to move away from a rigid project plan to an iterative process greatly facilitated my personal creativity and motivation. This iterative and explorative design process identified Strong Concepts which inspired me to study interactivity based on hints and insights from the stakeholders while using the device, instead of focusing on the aesthetics and superficial design.
7. CONCLUSION

For the conclusion, let us revisit the research question we initially focused on:

**How can we design interactivity for SAR reading at a public library?**

Mixed Reality is a promising realm where Interaction Design’s role is of utmost importance. In this report, I have carried out several design engagements using a spatial augmented reality prototype that I have constructed out of rudimentary hardware. The process was facilitated by my methodology of choice and the technological advancements of projection systems, previous research work within the field of mixed reality, and research on ergonomics and contexts of use. The combination of these created an interesting design space where Mixed Reality could be used in the two contexts: with children and academic environments at the library.

The key findings were distilled from the two workshops that covered the respective contexts. In our children’s workshop we identified and gauged the interest, design engagements, affordances, and features of the prototypes. Then later, in the academic workshop, we continued to test for meaningful interaction and features that would be valuable to professors and students alike. We now have arguments for both cases where the Mixed Reality Book can play an important role in making regular books come alive for children in terms of interactive illustrations and drawing, but also being a useful academic tool with a multitude of features augmenting regular books, research papers and documents.

It is now clear that the interactivity design for SAR reading should be user-centred rather than technology-centred. It was not difficult to develop the prototype and its interface; the difficulty was in finding meaningful interaction. We identified important design considerations and categories of interaction in the Mixed Reality Book. Some of these concepts have been tested with single and multi-users alike in library environments; these insights, stemming from a form of participatory design, helped me ground the work. To summarize our concepts:

**Interactivity in the Children’s Workshop (4.3.1), (11.2.7):**

- Interaction with Peripheral Holograms
- In-book Text Projection
- Use of Page Flipping to control Peripheral Content
- Illumination of Books for better concentration while reading
- Projection Mapping considerations when the book is moved around
- Sketching and Doodling

**Interactivity in the Academic Workshop (11.2.9):**

- Text Highlighting Affordances (4.3.2.3)
- Animation Controls of materials outside the book via UI (5.3.2)
- Book Edge Illumination (5.3.5)
- Document Uplink and Presentation (5.2.2)
- Natural Touch Input with Momentum (5.3.2)
- Multi-User UI Considerations (5.3.3)
- Responsive Design and spatial considerations for content placement (5.3.4)
- Annotation & Sketching (5.2.2)
- Accessibility Features for vision impairments (5.2.4)
- Live Analytics-enabled reading (5.2.3)

A summary of what has been done to acquire the knowledge in this project:

- Research through design was performed to rapidly prototype mini-studies.
- A workshop was performed in a library to identify meaningful interactions with children.
- The second workshop helped identify interaction in an academic context;
- Feedback and interviews were analysed which gave insight on:
Interaction Categories, where interaction is possible in this project.
- Interaction Insights, which outline design conventions to follow when creating content.
- Technical overview of metadata and the theorized device.

Through an analysis framework and a design perspective discussion, I also put forth new contexts of use of the project and created an open-ended design space where further scaffolding can be done. The project now exists as a foundation and initial blueprint for a thorough SAR solution that could be developed and deployed in libraries across the world. This, of course, is not without its challenges. The reflection of this report goes on to identify the social and technical barriers of the project, and especially the problem of content creation.

Will the Mixed Reality Book become a commonly seen technology in our libraries? It is still too early to say. While the concept feels very promising, I cannot put more undue emphasis on the fact that a project like this requires logistics that are outside of my scope. My wish, however, is to have an opportunity to continue developing this technology under an umbrella of a company or institution that has the resources to facilitate both further design research and the production of the device. In the meantime, I put my faith in the fact that this concept can be showcased in public with a potential to attract collaborators.

8. Perspectives

What started to improve the atmosphere while reading The Raven became a potentially powerful tool for play and academic reading. Our design space moved towards more practical and embodied applications after identifying meaningful interaction using this system. The further this project developed, the more use cases and design spaces were created (Figure 24); we only had a chance to explore two.

Figure 24. Potential Use Contexts

As projection technology improves and becomes more cost effective, it’s possible to see this technology being used in more and more aspects of daily life, academia, and business. The obvious use context in the libraries still has a lot of polishing and development left. The biggest obstacle is a chicken or the egg problem: whether peripheral reading can be created for the project. If there is content, then there are applications for this technology, but without it it’s nonsensical to be installing it in every library at universities. Moreover, with a sufficient prototype, such as the freestanding Mixed Reality Book / “Reading Lamp” device (as imagined in the second sketch (4.1)), this reading may be enabled in home environments.

In the future, I can see this technology branching out to facilitate reading in sectors such as finance, engineering, law, and medical fields. In fact, the Mixed Reality prototype has potential in improving societies through technology, as demonstrated in my peer’s work (Rohilla, 2018), where an AI assistant may facilitate interactions between citizens and governments. If content is created that provides meaningful information and interaction, all forms of paper-based text could be augmented, ranging from contracts to blueprints and medical history documents. Now that we’ve identified some of the affordances in this project, it’s possible to carry out further design exploration and start designing tangible content.

Lastly, implication of peripheral reading is, of course, not limited to Spatial Augmented Reality; the interactions and interfaces can be easily carried over into Augmented Reality glasses such as the Microsoft HoloLens (Savov, 2015) and Magic Leap. At that point the installation logistics for this technology will be negligible, but the issue of content will remain still.
ACKNOWLEDGEMENTS

I would like to express a big thanks to Oscar Clarsson, who has been sharing his research and relevant findings with my project and provided valuable expert feedback. I would also like to thank James Rasmussen who helped with creating some of the audiobook content and effects, as well as being a willing participant in the research and supporting me through my writing process. A big thanks to the staff of the Palanga City Library for providing a space and event to try this project.

Additionally, thanks to Kęstutis K. for giving insight into the world of book illustration and giving some ideas on what could be developed. Finally, a big thanks to my supervisor, Anne Marie Hanson, for supporting me and helping me throughout the development of this project and being a beacon of motivation and encouragement.
REFERENCES

9. Bibliography


## 10. APPENDIX A

### 10.1 AA.0 Research Diary

<table>
<thead>
<tr>
<th>Accessed</th>
<th>Item</th>
<th>Observations</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>04/02/2018</td>
<td>A Brief Rant on the Future of Interaction Design</td>
<td>Foundation for problem formulation and project idea – author does not like glass – criticizes Microsoft’s “A day made of glass” which I loved when I was younger. Challenged notion</td>
<td>Motivation for using paper and artefact-based interaction Critical outlook on glass</td>
</tr>
<tr>
<td>04/03/2018</td>
<td>Types of Reading by Maija MacLeod</td>
<td>Narrowing down exercise to determine the types of reading available. Mapping with possible reading situations identified (Section AA0.1)</td>
<td>Identification of different types of reading</td>
</tr>
<tr>
<td>04/04/2018</td>
<td>EFFECTS OF LINEAR TEXTS IN PAGE SCROLLING AND PAGE-BY-PAGE READING FORMS ON READING COMPREHENSION INTRODUCTION</td>
<td>General observations and comparison of iPad-style text scrolling and page by page flipping</td>
<td>Not applicable</td>
</tr>
<tr>
<td>04/04/2018</td>
<td>Peripheral vision</td>
<td>New possible direction to explore how peripheral vision may be used to read. Later abandoned due to insufficient studies within the area</td>
<td>Attempted at conducting a peripheral speed-reading demo</td>
</tr>
<tr>
<td>04/04/2018</td>
<td>Audio Content</td>
<td>Exploration in the use of audio effects when reading books – atmospheres, ambience, narration</td>
<td>Used audio in workshop</td>
</tr>
<tr>
<td>04/04/2018</td>
<td>The 7 Types of Readers - TheIslandReader.com</td>
<td>Identifying non-canonical types of readers to better understand the target audience (not used)</td>
<td>Not applicable</td>
</tr>
<tr>
<td>04/04/2018</td>
<td>Media Texts, Authors and Readers - A Reader - Google Books</td>
<td>Philosophical considerations on what media does to people, and what people do with the media. Possible relation to the role of Mixed Reality Book in a spectator context</td>
<td>Motivation for using Mixed Reality for reading</td>
</tr>
<tr>
<td>05/04/2018</td>
<td>When Psychology Meets Technology with Dr. Daniel McDuff - Microsoft Research</td>
<td>A podcast to explore the gap between human emotions and computers. A window into designing emotionally sentient agents</td>
<td>Considerations on including an element of emotional design</td>
</tr>
<tr>
<td>05/04/2018</td>
<td>Hamlet on the Holodeck - The MIT Press</td>
<td>A take on a classic where the story is being reshaped by the computer technology. Connection of digital environments with traditional narrative</td>
<td>Not applicable</td>
</tr>
<tr>
<td>05/04/2018</td>
<td>The Surface Texture Bible</td>
<td>Search for a sampler that would contain a mixed set of flat materials which could have been used in bodystorming as different materials (not paper) could be used with Mixed Reality Books</td>
<td>Not applicable</td>
</tr>
<tr>
<td>05/04/2018</td>
<td>02 Concept - IBM Plex</td>
<td>IBM’s new font – a look into the aesthetics of typography in the digital context</td>
<td>Used in in-book text projection demos</td>
</tr>
<tr>
<td>05/04/2018</td>
<td>Museums are the best place to find innovation in AR - VentureBeat</td>
<td>Possible exploration of a use context within museums</td>
<td>Discovered similar project, investigated its aesthetics</td>
</tr>
<tr>
<td>05/04/2018</td>
<td>Hanko Tsumugi Kosome</td>
<td>Encounter by accident, a sampler</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Date</td>
<td>Project Name</td>
<td>Description/Notes</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>09/04/2018</td>
<td>Textured 8.5x11-Cardstock Sampler</td>
<td>That fits the criteria. Unfortunately, the shipping times would disable this experiment</td>
<td></td>
</tr>
<tr>
<td>09/04/2018</td>
<td>Codex Seraphinianus</td>
<td>An encyclopaedia about a fantasy world written in an impossible language. A potential candidate for design engagements where the content is completely ambiguous</td>
<td></td>
</tr>
<tr>
<td>09/04/2018</td>
<td>Component-based Approach to Immersive Authoring of Tangible Augmented Reality Applications</td>
<td>A fantastic resource that suggests templates for authoring tangible reality applications. This could be used as a foundation to design content for Mixed Reality Boo</td>
<td></td>
</tr>
<tr>
<td>09/04/2018</td>
<td>OpenCV Marker Detector v0.1</td>
<td>Hardware/software specific exploration in search for AR Markers to identify and project content</td>
<td></td>
</tr>
<tr>
<td>09/04/2018</td>
<td>HyperCard Zine</td>
<td>A sideways exploration of ways applications could be created using point and click interfaces</td>
<td></td>
</tr>
<tr>
<td>09/04/2018</td>
<td>Two-perspective Projector</td>
<td>Using the same projector, it’s possible to create two or more interfaces on the same surface which is different depending on the angle you look at. Could be used as an interface utility for collaboration</td>
<td></td>
</tr>
<tr>
<td>10/04/2018</td>
<td>Microsoft IllumiRoom full demonstration</td>
<td>Core concept grounded after exploring IllumiRoom – periphery projection for Media and Games</td>
<td></td>
</tr>
<tr>
<td>10/04/2018</td>
<td>Room2Room</td>
<td>Use of projectors to create holograms of people as Skype calls. Potential use case in Mixed Reality Book co-work</td>
<td></td>
</tr>
<tr>
<td>10/04/2018</td>
<td>Steerable Augmented Reality with the Beamatron</td>
<td>A motorized platform that can change the angle and rotation of the projector. Considered in hardware props</td>
<td></td>
</tr>
<tr>
<td>10/04/2018</td>
<td>Designing Interactive Paper-Craft Systems with Selective Inductive Power Transmission</td>
<td>Potential use case for page flipping detection</td>
<td></td>
</tr>
<tr>
<td>10/04/2018</td>
<td>12 projects that enhance print books with technology</td>
<td>A great insight into the existing projects that augment paper reading</td>
<td></td>
</tr>
<tr>
<td>10/04/2018</td>
<td>Smart Text-Reading Glasses - Oton smart glasses</td>
<td>Glasses that can use OCR to read text aloud – a case for disabilities and Accessible Reading (implemented)</td>
<td></td>
</tr>
<tr>
<td>11/04/2018</td>
<td>Circuits on Tinkercad - Tinkercad</td>
<td>Educational tool that could be used with the project</td>
<td></td>
</tr>
<tr>
<td>11/04/2018</td>
<td>Mind Mapping 101- The Visual Way to Organize Information</td>
<td>Data visualization that could be used in conjunction with projected periphery to reference content</td>
<td></td>
</tr>
<tr>
<td>11/04/2018</td>
<td>Organizational Structure -- XMind Online Library</td>
<td>An example of a mapping of structures – considered designing the UX of the project using this software</td>
<td></td>
</tr>
<tr>
<td>12/04/2018</td>
<td>Speech to Text Demos</td>
<td>Audio content software solution for “The Raven”</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>Project/Resource</td>
<td>Notes</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>--------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>12/04/2018</td>
<td>Handholding, Remixing, and the Instant Replay: New Narratives in a Postnarrative World</td>
<td>A philosophical / theoretical view into modern storytelling</td>
<td></td>
</tr>
<tr>
<td>12/04/2018</td>
<td>DataTiles: A Modular Platform for Mixed Physical and Graphical Interactions</td>
<td>Seems to be like some of the earlier ideas - good references and research on interaction. Used gestures and text highlighting in demo</td>
<td></td>
</tr>
<tr>
<td>16/04/2018</td>
<td>Electrolibrary by Waldek Węgrzyn</td>
<td>Completely digital paper book with soldered pages – can be used as a controller for PC</td>
<td></td>
</tr>
<tr>
<td>16/04/2018</td>
<td>An information addition system on books using a projector-camera</td>
<td>Almost exactly the technical limitation of this project, unfortunately very brief – 2 pages. Only hardware Considered a similar method but discovered a better one later</td>
<td></td>
</tr>
<tr>
<td>17/04/2018</td>
<td>The Overhead Projector: Experimental Development Unit Report</td>
<td>Older research for when projectors were only becoming available Considerations on angling and shadows noted</td>
<td></td>
</tr>
<tr>
<td>18/04/2018</td>
<td>Project Xanadu</td>
<td>Fantastic project and resource that could have been all a project on its own. Using some of its design conventions for the interface Theorized paperless Academic Research Table, later abandoned as it detracted from the concept</td>
<td></td>
</tr>
<tr>
<td>18/04/2018</td>
<td>Schafer, R. Murray. The soundscape: our sonic environment and the tuning of the world</td>
<td>Philosophical look into soundscapes from a historical and ethnomusicological perspective Considered using for historical books and documents in mixed reality</td>
<td></td>
</tr>
<tr>
<td>18/04/2018</td>
<td>WHAT IS SUPERSENSE?</td>
<td>A consumer-focused solution for tangible products that are ordinarily physical. Support argument? Not applicable</td>
<td></td>
</tr>
<tr>
<td>18/04/2018</td>
<td>A Companion to Digital Literary Studies</td>
<td>A philosophical and social perspective on the role of digital books, hypertext and cybertextuality. Considered in Xanadu Academic Research Table</td>
<td></td>
</tr>
<tr>
<td>19/04/2018</td>
<td>Nanoleaf- Lighting that's Smarter by Design. - Nanoleaf.me</td>
<td>Smart lighting that can drastically change the atmosphere of a room – a use case for the mini light stud Considered in Smart Lighting Scenario</td>
<td></td>
</tr>
<tr>
<td>20/04/2018</td>
<td>OpenCV for Unity - Asset Store</td>
<td>Further hardware exploration in setting up motion tracking using the Kinect (partially complete) Used for hardware and software sketching, unsuccessfully</td>
<td></td>
</tr>
<tr>
<td>20/04/2018</td>
<td>The living book - A poetic mapping animation for the Hublot boutique in Lucerne.</td>
<td>A good example of a book that uses projected periphery Considered visual aesthetics</td>
<td></td>
</tr>
<tr>
<td>20/04/2018</td>
<td>Vytek-VR-Awesome</td>
<td>A list of VR resources for VR studies                                                    Not applicable</td>
<td></td>
</tr>
<tr>
<td>20/04/2018</td>
<td>Microsoft- RoomAliveToolkit</td>
<td>Microsoft’s toolkit to experiment with mixed reality Not applicable, tool did not work with Kinect v1</td>
<td></td>
</tr>
<tr>
<td>20/04/2018</td>
<td>Nikolaj Kunsthal byder på virtual realitymiddag i skammekrogen</td>
<td>Mixed Reality in a restaurant where a story is played on the dishes – possible context for peripheral holograms Considered visual aesthetics</td>
<td></td>
</tr>
<tr>
<td>20/04/2018</td>
<td>Setting Emacs Theme Based on Ambient Light</td>
<td>Considerations to include ambient lighting as a part of the experience Considered using ambient-light sensors to change the book’s brightness and contrast</td>
<td></td>
</tr>
<tr>
<td>23/04/2018</td>
<td>MirageTable</td>
<td>A Virtual Table solution with early examples of artefacts Considered visual and interactive aesthetics</td>
<td></td>
</tr>
</tbody>
</table>
10.2  [AA2] Design Engagements

10.2.1  Picking the Mixed Reality Type

Via AB1.8 VR Book
The purpose of the first design engagement was to test out low-fi prototypes with myself and a friend to see what design space is the most promising. This was conducted using Gear VR, and Pico Projectors.

A very rudimentary concept in Unity 3D has been prepared to showcase the capacity in VR. Overwhelmingly, the SAR experience was rated better, whereas VR has been described as “disorienting” and “low resolution”. Henceforth, SAR was the primary hardware interest area.

10.2.2  The Raven

Via AB1.1 Peripheral Reading (The Raven)
The Raven Demo was the first immersive concept that bundled projection of text, peripheral experiences and audio.

The purpose of the design engagement was to identify the role of peripheral reading as well as get a good feel for it. Unanswered, however, was the role of Interaction Design in the context of this reading, which is why the concept had to be evolved further.
10.2.3 Workshop 1

Via 4.1.1 Local Library & AB1.7 Cinematic Book

The first workshop’s design engagement precluded the testing of the cinematic periphery with children. The focus was on social aspects, elements of co-design and play.

A Hi-Fi prototype was deployed in the workshop which targeted the implementation, role and look and feel of the concept.

10.2.4 Workshop 2

Via 4.2.1 Orkanen Library & AB1.9 Academic Dashboard & Reader

For our culmination of design engagements and ideas developed so far, the 2nd workshop’s design engagement intended to test out a vast array of features, which precluded a prototype both software and hardware that covered everything from the technical semantics to the interaction, aesthetics and emotions.

The imagined situation was a Study space with a reality check on the features that this concept afforded.
10.3 [AA3] Ideas

This section covers the ideas that were suggested during workshops by Stakeholders. I decided to separate them into segments that could be tested and analysed further.

### 10.3.1 General User Testing

<table>
<thead>
<tr>
<th>Suggested by</th>
<th>Idea / Observation</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classmate</td>
<td>You could use Project Xanadu as an interface to display and analyse research documents with this.</td>
<td>Enabled and Tested</td>
</tr>
<tr>
<td>Friend</td>
<td>The book could basically be a movie at this point – why not include animation stills from popular books/movies?</td>
<td>Argued against (Substitute for imagination)</td>
</tr>
<tr>
<td>Friend</td>
<td>Why do you need a book? You could just use the surface as a computer interface.</td>
<td>Argued against; but there exists a case for it</td>
</tr>
<tr>
<td>Colleague</td>
<td>This system could be used to analyse financial statements using live bars and graphs and current market information.</td>
<td>Considered, enabled with other areas</td>
</tr>
<tr>
<td>Friend</td>
<td>VR could be used to create a focused environment where nothing else exists except for the text. Imagine a complete black void with only the book and nothing else – for me this might be an amazing experience for reading.</td>
<td>Considered, but ultimately discontinued as a concept</td>
</tr>
<tr>
<td>Family member</td>
<td>I can imagine reading in a standing context, if this system could project text at any place on the floor it would be great.</td>
<td>Argued against due to ergonomics</td>
</tr>
</tbody>
</table>
| Family member| This project can be used to display recipes on a kitchen counter. | Partially Tested  
Discovering similar project |

### 10.3.2 Workshop 1

<table>
<thead>
<tr>
<th>Suggested by</th>
<th>Idea / Observation</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Library Staff</td>
<td>I see potential in educational situations – perhaps a geographical demo where maps can be displayed alongside the atlas.</td>
<td>Partially Tested</td>
</tr>
<tr>
<td>Child</td>
<td>Is it possible to play games on it?</td>
<td>Considered running applications</td>
</tr>
<tr>
<td>Library Staff</td>
<td>This could also be used for play, have you considered that?</td>
<td>Relayed to supervisor</td>
</tr>
<tr>
<td>Supervisor</td>
<td>Building on the play idea – this could be made into an experience where encyclopaedias can transform the room / floor into a play area where children can engage with toys.</td>
<td>Considered, enabled with other areas</td>
</tr>
<tr>
<td>Book Illustrator</td>
<td>I think it’s important to think about how to design these experiences; for me, personally, it would take some time to learn how to create that.</td>
<td>Considered and documented</td>
</tr>
<tr>
<td>Friend</td>
<td>The drawing experience could be transferred over to make actual notes and annotations.</td>
<td>Enabled and Tested</td>
</tr>
<tr>
<td>Child</td>
<td>Is it possible to change the environment like in Minecraft?</td>
<td>Considered as a design feature</td>
</tr>
<tr>
<td>Library Staff</td>
<td>It’s possible to dedicate a section of the library specifically for these types of holographic books.</td>
<td>Considered as an alternative to digital library picker</td>
</tr>
<tr>
<td>Child</td>
<td>It would be good if the book was movable everywhere.</td>
<td>Explained that that’s the goal, but technical limitations do not allow for it yet</td>
</tr>
</tbody>
</table>
## 10.3.3 Workshop 2

<table>
<thead>
<tr>
<th>Suggested by</th>
<th>Idea / Observation</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervisor</td>
<td>The prototype needs to be tethered to the ceiling a bit better as it may be dangerous.</td>
<td>As the prototype did fall down a couple of times, I decided to construct a laser cut box for it.</td>
</tr>
<tr>
<td>Student</td>
<td>I like the fact that you can select text – have you considered Sharing and Collaboration features?</td>
<td>Partially Tested</td>
</tr>
<tr>
<td>Student</td>
<td>The book’s environment can obviously accommodate several books at the same time – have you thought about that?</td>
<td>Considered in the design of the periphery CSS</td>
</tr>
<tr>
<td>Student</td>
<td>I suggest using RFID to determine what book is on the table.</td>
<td>Enabled</td>
</tr>
<tr>
<td>Student</td>
<td>Because it’s dark, I recommend illuminating pages when they’re being read.</td>
<td>Tested and enabled</td>
</tr>
<tr>
<td>Student</td>
<td>Could the neon glow around the edges of the pages be used to identify specific segments of the book?</td>
<td>Considered (the glowing edges were motion tracking markers, but may be used in this context)</td>
</tr>
<tr>
<td>Student</td>
<td>Is there an option to change the transparency of the periphery?</td>
<td>Not Tested</td>
</tr>
<tr>
<td>Student</td>
<td>What happens when the book is taken off the table?</td>
<td>Considered pausing the experience</td>
</tr>
<tr>
<td>Professor</td>
<td>I see this could have a “home screen” like interface that could contain some library features.</td>
<td>Developed a concept and tested</td>
</tr>
<tr>
<td>Professor</td>
<td>There is a case for analytics and statistics for this – have you seen the PEARLS system?</td>
<td>Developed a concept and tested</td>
</tr>
<tr>
<td>Professor</td>
<td>I don’t like the virtual electronics bit; I think it’s still better to have them for real.</td>
<td>Scrapped</td>
</tr>
<tr>
<td>Supervisor</td>
<td>I can imagine an embodied experience where the projected periphery can also draw on your body – for example, if you want to learn about anatomy you can “paint” yourself with x-ray so that the projection makes your skeleton be seen on the surface of your skin and clothes.</td>
<td>Considered, not tested</td>
</tr>
<tr>
<td>Professor</td>
<td>High round tables I found are great for collaboration; this could be something to consider when designing the environment.</td>
<td>Considered in the design of the table</td>
</tr>
<tr>
<td>Student</td>
<td>It would be amazing if reading progress / notes would be able to be saved somehow.</td>
<td>Partially Tested</td>
</tr>
<tr>
<td>Student</td>
<td>What if the book in the library isn’t available? Is it possible to call for a virtual book on this table as an alternative?</td>
<td>Considered but may be outside the design space</td>
</tr>
<tr>
<td>Student</td>
<td>The pixilation of the graphics may be distracting while reading – couldn’t you use a higher res projector?</td>
<td>Explained that a 4K projector may be used instead</td>
</tr>
<tr>
<td>Student</td>
<td>Could this system be used in classrooms on desks?</td>
<td>Considered but commented that a substantial investment may be necessary</td>
</tr>
<tr>
<td>Student (Follow-up)</td>
<td>In Blade Runner they have a projector that runs on a rail to project holograms within a house – could this be a potential solution?</td>
<td>Argued against moving parts as moving periphery does not have a case for reading</td>
</tr>
<tr>
<td>Student</td>
<td>I see how this could be great to avoid distractions – have you considered that aspect?</td>
<td>Considered</td>
</tr>
</tbody>
</table>
10.4 [AA4] Process Mapping

10.4.1 Gantt Chart

10.4.2 UX Map
10.4.3 Triangulation / Mapping Exercises
11. APPENDIX B

11.1 Device Prototyping

To develop a SAR prototype further I conducted some sketching, both physical and digital. The semantics or the shape of the device were not important at this stage – the goal was to develop a hardware prototype that would enable the potential periphery contexts. To accomplish this, a projector, a webcam and/or a Microsoft Kinect would need to be set up at a specific angle, along with an available work surface and physical book to project on.

11.1.1 1st Gen Development

A hardware solution for a Mixed Realty Book augmentation prototype was constructed using the following hardware and software:

- A Short Throw Projector
- HDMI and Power Cables
- Crudely constructed metal framework for latching on
- A ThinkPad x220 Laptop with Microsoft Windows
- Rainmeter
- Media Player Classic: Home Cinema

The projector was mounted on top of 2-meter-tall bookshelves, specifically matching the bookshelves at the library. (It’s worth noting that a standalone rigid frame (11.1.4) was considered before applying a simpler ceiling/light mounted solution in later prototypes.)

After determining the most optimal angle, viewing distance and luminous efficiency, measurements have been made on the floor, table and glass table to account for the optical properties of the projector. Unfortunately, the model of the projector that was being utilized did not preclude software calibration and had to be adjusted manually for each surface of variable height.

![Figure 10: First generation bookshelf-mounted prototype](image)

After putting the necessary elements together, the prototype was installed in the library of my office, mounted above the bookshelves for optimum height. Underneath, a 60cm high IKEA table was used to receive periphery. This prototype was also used to demonstrate the concept to library staff before the workshop (Figure 10).
11.1.2 2nd Gen Development

After a few hardware sketching sessions, studies and re-framings, the projector hardware has been significantly upgraded by adding the following components and conditions:

- Microsoft Kinect 1st Generation (Figure 11)
- Projector Ceiling mount that’s been modified and inverted
- A part of a heavy worktop for secure bearings
- OpenFrameworks
- A more sophisticated projector (Figure 11)

![Figure 11. Second Generation Prototype](image)

The higher resolution and much brighter and quieter projector solved some of the technical issues that I encountered with the draft version of the hardware prototype. The addition of the Kinect and Open Frameworks has enabled more powerful software sketching and experimentation – not without its challenges, however.

Overall, the second generation of this prototype seemed suitable to be deployed in the upcoming Library demonstration as it had sufficient software and hardware fidelity. The device has been miniaturized and embedded into a wooden box that’s been laser cut with a handle. The handle is designed to be mounted onto the lights of the ceiling in the Orkanen building.

Throughout the Studies, the 2nd generation prototype was used extensively without major modifications – the only changes were made only in calibration and software sides. Some transportation logistical issues have prompted me to design an outline for a 3rd generation prototype that would be more suitable for transportation.
11.1.3 Third Generation Device Concept

Considering the challenges and interaction semantics, I took the liberty to conceptualize a third-generation prototype that could be the next phase for the development of this project (Figure 23). Basing the prototype on the second-generation, it retains the qualities of being able to be easily ceiling-mounted by attaching it to the light fixtures.

![Figure 23. Third-generation composite periphery system](image)

Moreover, the device contains theoretical but possible hardware features that would solve issues such as noise and depth detection. The assumptions for this technology are based on existing commercially available projection systems, such as the Sony 4K SXRD and Sony Xperia Touch

![Figure 23A. Bottom, Front and Right of the proposed concept](image)

<table>
<thead>
<tr>
<th>Table 12. The physical properties of this device</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Width</strong></td>
</tr>
<tr>
<td><strong>Height</strong></td>
</tr>
<tr>
<td><strong>Length</strong></td>
</tr>
<tr>
<td><strong>Weight</strong></td>
</tr>
</tbody>
</table>

The key hardware-technical aspects of the device theorized:

- Built-in Kinect styled sensors
- Keystone Angle Flipping
- Digital Focus-Depth Adjustment
- Ethernet Port
- AC 220V Input
- Passive Water-cooling

An additional software solution for metadata, OS and logistics is proposed in Appendix B 11.8
11.2 [AB1] Mini Studies

This section of the Appendix includes some of the design engagements which have been an important aspect of RtD in this project.

11.2.1 AB1.1 Peripheral Reading (The Raven) (Watch)

The first and original problem formulation, framework and design space was formulated within the context of peripheral reading in a leisure context. This precluded sci-fi, fiction and poetry. A brief prototype was sketched with this design engagement that included Edgar Allan Poe’s “The Raven”. This interaction can be observed in the Video Journal.

After testing this concept with myself and users, I have inferred that although it is a very impressive in terms of visual aesthetics and off-beat way of reading, it did not contain sufficient Interaction Design attributes to be continued further as my thesis project, so it was suspended.

11.2.2 AB1.2 Codex Seraphinianus (Watch)

Codex Seraphinianus is an illustrated encyclopaedia of an imaginary world, written in a cipher alphabet in a constructed language that is impossible to comprehend. This book’s intended ambiguity was used to test out experiences that are secondary to the reading process:

- Validation of the medium
- Emotional impact
- Flow regardless of content

The sequence was embodied and included illustrations that leaked onto the hands and body of the reader. However, as with The Raven, I was unable to identify any meaningful interaction that would justify the installation of an expensive projection system in the living room.

11.2.3 AB1.3 Smart Lighting (Watch)

A sideways design experiment which detracted from the projection concept I have been working with. This sequence considered the use of smart lights to improve the atmosphere of reading. A possible futures scenario was constructed with a Video prototype where this is illustrated.

In parallel, an Arduino solution facilitating this interaction was prototyped and constructed.

Upon reality check and further review during supervisions, the smart lighting was deemed to have detracted too far from my original research question. I considered using some of its elements, such as projecting colour hues onto pages depending on the context.

11.2.4 AB1.4 Mixed Media (Watch)

This brief design engagement looked at the possibility to create atmospheres, both audio and visual, within the books themselves. A demo with a sea shore with waves coming in and out was perceived to be relaxing and atmospheric. However, the concept was later discontinued as well because effects behind the text could become distracting after a while.

11.2.5 AB1.5 Interfaces (Coverflow) (Watch)

When the concept was still considered to be used with blank books, I tried out several interfaces that could be shown on blank pages. This interface shows a book selection sequence. As with the other concepts, this idea was later scrapped and transformed into other concepts. Blank books were no longer a focus beyond this stage.
11.2.6 AB1.6 IBM Centric (BIM Visualizations) (Watch)

During my exchanges back and forth with IBM IdX, I developed some concepts based on their use case scenarios. One area of interest for them was the use of Augmented Reality to extrapolate BIM documents and blueprints.

To demonstrate a case for this using Mixed Reality Book, I re-designed the stage for peripheral reading to have projected content on the floor and on a glass IKEA table. Any blueprint and content that was put on the table would be identified using AR Markers with a BIM 3D model loaded in its periphery on the floor. The user then would be able to manipulate the viewing angle, interact with the model and make basic adjustments using a small circular stylus that could be moved around on the paper blueprint.

A video demonstration can be seen in the Video Journal

This design exploration enabled for interesting ideas and considerations in the design of peripheral effects which may not even need to be bound by any surfaces or table, especially within the context of play.

11.2.7 AB1.7 Cinematic Book (Children’s Animations) (Watch)

The first workshop design engagement precluded a living book that would contain peripheral effects and animations. A very limited demo was prepared to gauge the reactions from the stakeholders. The execution of the workshop and results are available in the earlier sections of the report.

A video demonstration can be seen in Appendix C.

Considering the IBM Centric demo, me and my supervisor theorized the possibilities where a children’s encyclopaedia may explain how an electric car works, and upon interaction the mixed reality book could transform the floor into a city-like grid where children could engage with their toys.

11.2.8 AB1.8 VR Book

A very brief design engagement was performed using VR/AR Technology. Because the mixed reality peripheral effects could be easily carried over into VR/AR and experienced in a similar way, I wanted to see how this would look like with the technology that we have today. I used Gear VR with the Samsung S8+ and a rudimentary prototype built in Unity 3D.

The results were inconclusive, as there were technical challenges with the spatial calibration due to Gear VR’s lack of 6-axis sensory input. However, the initial impression was predominantly negative and neither I nor my friend enjoyed reading in a virtual environment. The concept was dropped in the beginning of the project, but this design engagement only proved that I made the right decision to focus on physical books.

11.2.9 AB1.9 Academic Dashboard & Reader (Watch)

One of the last design experiments included the testing of David’s ideas and concepts after our workshop in the Orkanen Building. This included a dashboard system which would detect the Multicard, the book and research documents that were put on the table. While this concept is the most functionally impressive, it is also the most incomplete one; due to time considerations I decided not to explore the tangibility of it any further and instead leave the design space open for now.

11.2.10 AB1.10 Future of Government 2030 Brief Study (Watch)

After communicating with my peers about their projects, I stumbled upon a case where the Mixed Reality Book system may be used to facilitate interaction. A project for “Future of Government 2030” precludes new technologies to access, communicate, produce and exchange information. There was a case in this project to showcase the capacity of an AI-enabled SAR solution which may be installed in public institutions to help citizens deal with issues in their city. A video is shown in the Appendix section that opens yet another design space where Mixed reality is also mixed with AI and politics.
11.3 [AB2] Metadata Structure

Another logistic of deploying the Mixed Reality Book is the consideration for how Mixed Reality content may be embedded into the experience. Tying physical books to digital content is an issue that has been tackled more than once by various institutions.

In our context, within libraries, the most obvious choice is the use of RFID tags on tables to uniquely identify the type of book that is being enabled. As most libraries contain digital versions of their books, we can infer that the access to these digital versions will be a negligible hurdle and we can come straight into designing a metadata structure.

I envision periphery metadata to be an auxiliary file to the digital “.epub” of the book. The “.emrb” file extension could be a ZIP based container which would include HTML periphery experiences alongside XML metadata which ties pages, or the content of the book to particular peripheral experiences. These metadata containers would be bundled alongside the library database for fast lookup. The condition for this to happen also requires a foundation renderer which is discussed in the next section.

11.4 [AB3] Kinect Alternatives

Due to the discontinued Kinect, we are faced with a major engineering challenge in identifying possible alternatives that would replicate the functionality. I identified that the patents for the Kinect technology have been transferred to Apple Inc. and are, at the time of writing this Appendix, used as major components within the iPhone X. Complete market-ready solutions exist, however, here is a possible list of technology that may be used for further prototyping and potential development:

- VicoVR
- Orbbec Astra / Persee
- Stereolabs ZED
- OpenPose
- Intel RealSense SR300

The most promising of the five and the closest to the Microsoft Kinect is the Orbbec Astra/Persee. It appears to offer the technical capabilities of the Kinect and an open software framework / SDK. It also offers a miniaturized version that could be readily deployed within further prototyping.

---

![Figure AB3.1 8cm x 2cm x 2cm Orbbec Astra Mini S](image)
11.5 [AB4] Detecting page flipping

An important interaction point, both from a user’s perspective and from a technical one, is the ability to naturally navigate a book through page flipping. This simple and natural affordance is, without question, a major part of the experience; therefore, I have been trying to accommodate this interaction from a technical perspective.

Initially, prototyping with Arduino was done with a multitude of sensors, including the following tried and failed hardware experiments. All these devices were supposed to be attached to the book being read.

<table>
<thead>
<tr>
<th>Item</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrared Light Emitter and Receiver</td>
<td>Use of an IR light emitter on the top of the book, and one on the bottom to see when a page has passed through. The results were inconclusive as I managed to destroy the IR Light emitter upon applying incorrect voltage to it. A replacement was sourced from an old remote control but used in the Smart Light case</td>
</tr>
<tr>
<td>Proximity Sensor</td>
<td>This feature used a Proximity Sensor to determine when a page has passed over it. The concept seemed to have worked but was wildly inaccurate as it would often detect the movement of the hand as a page flip. It also did not know whether the page was flipped forward or backwards</td>
</tr>
<tr>
<td>Collision Detection</td>
<td>The most accurate and systemic solution which can be observed visually in the Video Journal at AC2.6; unfortunately, not a perfect solution still because it also could not determine the direction of the pages</td>
</tr>
</tbody>
</table>

An accurate solution that does not require any additional hardware or modification of the book is very much preferred. The most obvious but overlooked solution was the use of Microsoft Kinect and its built-in high-resolution camera to identify the text using OCR and approximate it to the location of the book in its digital variation. Then, using the metadata framework (conceptualized in the further sections), determine the most fitting periphery effects and project it onto the surface and the book. I conducted very basic OCR tests with a webcam which has shown to be very effective, especially in the context where a book is already identified with RFID. It’s entirely possible to identify books with a lookup engine that do not have RFID, but the accuracy may suffer. Additional usability testing needs to be conducted to greenlight this concept.

11.6 [AB5] Projector Physical Specs and Light

This Appendix section covers some of the physical properties of the projector, the table and the environment that should be considered in further prototyping.

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projector Height</td>
<td>An overhead location at least 2m from the floor.</td>
</tr>
<tr>
<td>Keystone flipping</td>
<td>This allows to angle and align the projection for angled surfaces such as an adjustable table</td>
</tr>
<tr>
<td>Lumen Efficiency</td>
<td>The projectors I prototyped with ranged from 600-1000 Lumen. This is far too dim for a sufficient peripheral projection quality in daylight. Brighter projectors should be considered for future prototyping</td>
</tr>
<tr>
<td>Mechanical vs Digital Focus</td>
<td>Our prototypes required mechanical focus to make sure the image is crisp. Digital focus is preferred</td>
</tr>
<tr>
<td>Mount</td>
<td>The projector needs to be able to be overhead – this may preclude a construction of a frame, a mounting device for book shelves, or a ceiling mount</td>
</tr>
<tr>
<td>Noise levels</td>
<td>Our prototype projectors were too noisy for a good peripheral reading experience</td>
</tr>
<tr>
<td>Power Source</td>
<td>A power source is necessary for the components</td>
</tr>
<tr>
<td>Internet Access</td>
<td>A fast Wi-Fi connection is crucial for fast metadata lookup and downloading</td>
</tr>
</tbody>
</table>
11.7 [AB6] Child Psychology in doodling

While searching for inspiration in children’s books, I encountered an old Pinocchio story book that had its illustrations drawn over crudely with a pen.

After consulting members of my family, I identified that the book might have belonged to one of my cousins. The doodling drew my attention because of certain patterns that could be observed:

1. **Rating System**
   It appears that all characters within the books have numbers in them. Because the maximum grade in the country where my cousin was born is 5, and the minimum 1, we can infer that these numbers are ratings of what characters she liked and did not. Moreover, sometimes characters have several of these ratings, which might imply that she did several rounds on this book. Further inferences on the designs of the characters can be identified such as low ratings of bug-like creatures that may tie into Arachnophobia which I can personally attest is the case.

2. **Decorating the Good Guys**
   Another feature is that she kept adding the crown to the character that she liked the most.

3. **“Uglifying” The Bad Guys**
   The negative characters seem to have received decorations as well, usually in the form of making their teeth ugly or putting emphasis on negative facial features.

Overall, the exercise seems to showcase empathy of a child while consuming the illustrations of the book. Judging from the doodles, we can assume that the child did not have reading capacity at this age; therefore, these could have been drawn at 2-3 years of age. It’s fascinating to see how despite not being able to read, the child identified the characters and gave them attributes ranging from decorations to ratings.

This kind of agency should be preserved – doodling in books is a common activity amongst children, albeit often punishable. It’s possible that this design space could be explored further to provide arguments in Mixed Reality Book where drawing and doodling can be facilitated without destroying the book. This is explored in the first workshop in Sketching.
11.8 [AB8] Foundation Renderer

I theorized ways this technology could be implemented to be widely used with existing software and hardware solutions. Although I considered designing and developing my own programming language and visual framework, I asked myself – why re-invent the wheel? All the capacity for peripheral reading can be provided by HTML5, CSS and JavaScript. These web standards are familiar and well-polished.

Therefore, the foundation renderer for this project would be Web Kit based, on the Chromium project. Chromium is an open-source Web browser project started by Google, to provide the source code for the proprietary Google Chrome browser (Chromium Project, 2009). Modifications for the renderer would be required to preclude parsing of information from the Kinect (or alternative) interfaces. Once all the input interaction templates are designed, the foundation renderer respond by providing the metadata content for peripheral reading. An abstraction layer for GUI events may be required to be rendered on top, in parallel or as a separate system. This is because the static periphery content is independent of the possible physical interactions and may become a problematic combination if used together. However, to leave space for new interactions that could be embedded in the metadata itself, we will consider the possibility of providing this in the Designer Mode.

Here is a preliminary diagram for Chromium Based foundation renderer.

![Functionality Diagram for a Chromium Based Solution](image)

Figure AB8.1: Functionality Diagram for a Chromium Based Solution

This simplification of the software would also assist in miniaturizing the hardware and considering alternatives to Microsoft Windows. A prototype for the following diagram can be constructed using a Raspberry Pi 3 or similar; it’s important to note, however, that further testing of the hardware may be required, if the metadata contains High Definition video material.
11.9 [AB9] Developer Mode

To consider the reality of this project is to also consider the tools that would make it a reality. I precluded a conceptualization of a WYSIWIG Editor called the Mixed Reality Book Developer Mode. This mode is an editor which is based on HTML / CSS and JavaScript to create Mixed Reality content. Conforming to HTML5 standards, this would allow for a very powerful and modern standard that’s also accessible technologically to most designers and programmers. The idea came as an obvious extrapolation of the content creation process, and the problem of the content outlined in the challenges section.

The interface includes the active design area with a re-sizable table and shape, a movable Person POV character, the main toolkit, and code editor on the right. The purpose of the visual interface is to give as realistic look as possible when designing for mixed reality. As the metadata would be CSS based, Responsive Design guidelines should be observed which would allow wiggle room for tables of different sizes.

Additionally, the centrepiece of the visual editor would include a collection of physical books that can be overlaid onto the table to see how they work with the peripheral content. This is important because the designer be mindful of where the book is placed and how the content should respond.

The editor allows designers to create peripheral content; animations, text, drawings, referencing systems. But also, it’s considered to allow designers create interactions – GUI events, menus and features that were first to be “air gapped” from the editorial design space. This is a philosophical design choice that hasn’t yet been fully analysed – how much freedom should content designers be given over the periphery? A collection of design recommendations was compiled from our workshop results – recommendations that identify delimitations and affordances of peripheral interaction. Therefore, development of documentation should be an important goal in the further development of this project to outline design conventions and rules so that we can avoid bad interaction design.
12. APPENDIX C

12.1 [AC1] Treasure Planet

This movie has been released in 2002 and has created a lasting impression on the features of Augmented Reality and Digital Reading as imagined in the future. 16 years later, the technology to enable these features is available and is being adopted widely. In our project I attempted to re-create some of the features of this book; upon further reframing I found that there are more engaging and more tangible contexts of use.

The Treasure Planet book has been instrumental in the inspiration and analysis of the design space and demonstrates the influence of media and sci-fi bringing fantasy technology into reality. As interaction designers, we must remember that we also have the capacity to create these alternative futures. Let us look at the alternative future that we’re presented with in this scene:

Available online: https://www.youtube.com/watch?v=63g4zZ2JxXE

As we can see from Figure AC1.1, the child is in the process of reading an augmented reality-enhanced book about pirates. This is facilitated by four projectors embedded into the book that we can see in Figure AC1.2. It can be theorized that the book has an embedded power source, a controller and potentially sensors for motion tracking. In Figure AC1.3 we can see the page come alive as a hologram comes out of the book. Unfortunately for us, the holographic technology that can attach itself to thin air is currently very limited, so this book is not entirely possible to do with today’s tech. Lastly, we see tight coupling with the traditional notion of books where the interface precludes page flipping to continue the story (Figure AC1.4). Here are the 3 analysed qualities of it:

<table>
<thead>
<tr>
<th>Instantaneous, graduated and co-located design</th>
<th>Can be used anywhere (possibly indoors), anytime, as a book</th>
<th>Non-ambiguous qualities of interaction</th>
</tr>
</thead>
</table>

Treasure Planet is © 2002 Copyright Disney Corporation. Fair use policy is enacted on this content as it’s a commentary on the work. Still images are sourced from YouTube.
12.2 [AC2] Video Journals

This section contains previews of initial “mini studies” that were performed throughout the entire process of the project. A wide range of mini studies were visualized.

Digital Version: https://youtu.be/GN59oheTGCs

Narrated Version: https://youtu.be/gcBz6zCsuiM

Each thumbnail represents a timestamp within the video; thumbnails are clickable with a direct hyperlink to the specified time. A reference to this section precludes the link to the video of the thumbnail.

AC2.1 Original “The Raven” Periphery Experience Demo
AC2.2 Infrared Light control using Arduino
AC2.3 Theorized Light-controlled atmospheric effects
AC2.4 Coverflow interface sketch for book selection
AC2.5 Embodied Codex Seraphinianus periphery demo
AC2.6 “Living” pages with ambient backgrounds
AC2.7 Collision Detection Sensor Experiment for page flipping
AC2.8 IBM-centric BIM architectural visualization demo
AC2.9 Immersive “Spaceflight” demo with an e-reader
AC2.10 Cinematic Book – children’s illustration holograms
AC2.11 Orkanen Library Dashboard Interface
AC2.12 Future of Government 2030+ Design Probe

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