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Are Digital Children's Books Accessible to Blind Parents with Sighted Children?

THESIS

submitted in partial satisfaction of the requirements
for the degree of

MASTER OF SCIENCE

in Informatics

by

Jin Seo Kim

Thesis Committee:
Associate Professor Stacy Marie Branham, Chair
Associate Professor Anne Marie Piper
Professor Gillian R Hayes

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ABSTRACT OF THE THESIS

Are Digital Children's Books Accessible to Blind Parents with Sighted Children?

By

Jin Seo Kim

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Associate Professor Stacy Marie Branham, Chair

Assistive technologies offer numerous benefits for people with visual impairments (PWVI) when reading books in digital formats. Over the past decade, researchers have focused on exploring and enhancing the accessibility of digital book formats for PWVIs; yet, a recent study revealed that PWVI who are parents do not use digital books to read with their children. Scientists do not yet know why this is the case; are digital children's books inaccessible, or do they fail to meet the needs of co-reading? This thesis presents (1) a content analysis of the accessibility of 14 digital children's books, and (2) an interview study with five blind parents about their preferred co-reading technologies with their sighted children. This study reveals that the digital books sampled provided poor accessibility; most notably, the study underscored the absence of any form of image accessibility. Moreover, this research identified that blind parents do not desire to use digital books when reading with their children, because most often they read before bedtime, and they want to avoid using screens. The key contribution of this work is to identify the factors of blind parents not using digital books with their children, and insights into the design of assistive technologies for co-reading, emphasizing blind parents' preference for physical formats of children's books when co-reading.

Chapter 1

Introduction

Over the past several decades, there has been a noticeable shift in reading format practices, from print books to digital books, due to the latter being lower cost and offering an enhanced, more accessible reading experience over print books [65, 88]. This transition has also extended to visually impaired individuals who, in the past, relied on Braille books or audiobooks. The advent of assistive technologies, including screen reader and OCR text recognition software, enables blind people to access mainstream digital book formats (e.g., EPUB, MS Word, PDF) from mainstream vendors (e.g., Google Books and Amazon Kindle) on mainstream devices (e.g., mobile phone, laptop, and tablet computers) [79]. These technologies have substantially improved opportunities for blind people to access reading materials. For instance, a previous study of 75 visually impaired people about their knowledge of digital book formats and the accessibility of reading digital books found that though there are some advanced functionalities required to be more accessible to fulfill participants' needs, assistive technologies such as book navigation by chapters and paragraphs supported and enhanced accessibility for their educational reading progress [64]. To keep a higher level of accessibility in digital book reading, prior studies focused on designing a digital book format and system that is integrated with more advanced and accessible functions for

visually-impaired individuals [21, 30, 82].

Although assistive technologies offer numerous benefits for individuals with visual impairments, parents with visual impairments often do not rely on them when reading with their sighted children. Instead, they opt for conventional methods such as Braille [20, 87]. Parents with blindness commonly use twin-vision books and external Braille displays to aid their understanding of the story, allowing them to memorize and even create imaginative narratives [87]. Some parents utilize audiobooks, which can be considered a form of text-to-audio technology. However, negative perceptions towards audiobooks, such as the presence of narrators and irritating voices, have been reported. Furthermore, blind parents have highlighted specific technological barriers they encounter when using assistive technologies on their daily devices, such as phones [87].

In addition, blind parents face unique difficulties when accessing children's books compared to sighted parents. Printed children's books can be costly, of varying quality, and challenging to acquire for blind parents [87]. To ensure an equitable reading experience, digital books should provide the same level of accessibility as those available to sighted parents. Digital book providers such as Bookshare (a digital book provider for people with disabilities) and Seedlings (offering digital and physical books, including Braille, for blind parents and children) have made efforts to address the needs of individuals with disabilities by providing accessible books. However, blind parents still face hurdles in acquiring these accessible digital books via their devices, which may have accessibility limitations, similar to the challenges they encounter with acquiring printed books. While digital book providers cater to individuals with disabilities, blind parents may face restrictions when accessing digital books from mainstream providers when disability-specific services are unavailable. These questions led us to our initial research questions:

- **RQ1:** What is the current state of accessibility of digital children's books from a

mainstream digital book provider (Google Books)?

- **RQ2:** Do blind parents of young children (ages 0 to 8) use digital books to read with their children? Why or why not?

To address the first question, I collected 14 digital books from Google Books and conducted a content analysis to assess accessibility. The content analysis includes three aspects of accessibility of digital books: book metadata accessibility, book format accessibility, and image accessibility. The study revealed that poor image accessibility is provided in the sample books. Specifically, we do not find accessible images in our children's book samples. There are also general accessibility issues that might render digital books unsuitable for blind parents to use with their children when co-reading.

To address the second question, we conducted semi-structured interviews with five blind parents to inquire about their experiences and perspectives on using digital books for co-reading. Most participants indicated that they prefer to use print books rather than digital books because they think the visuals on physical books are essential for children's development, and digital books are inappropriate for co-reading scenarios.

Prior research primarily focused on how to enhance assistive technologies to support people with disabilities and how digital technologies should support collaborative co-reading practices [21, 30, 34, 35, 82]. There has been little empirical work on assistive technologies used when blind parents co-reading with sighted children and understanding the benefits and drawbacks of using digital books instead of conventional co-reading methods. Compared to prior works, this paper provides an empirical contribution to gathering the accessibility level of digital books from online digital book providers and authentic digital book use experiences for co-reading from blind parents with their children. It provides future implications on the possibilities of digital book use in co-reading practices.

The paper is organized as follows: Chapter 2 introduces related works of this paper; Chapter

3 explains the method I used for the research; Chapter 4 reports the findings from content analysis and interview study; Chapter 5 brings up discussion, conclusion, and limitations of the work.

Chapter 2

Backgrounds and Related Works

2.1 Background: Screen Readers and Image Accessibility

The screen reader is a type of assistive technology that enables blind and visually impaired people to access and navigate texts and images on electronic devices with screens, using text-to-speech or Braille display output [11, 21, 64, 70]. The first version of the screen reader for people with visual impairment (PWVI) is developed in 1986 by Jim Thatcher, an accessibility researcher from IBM [16]. As its successor, Ted Henter, who is a blind programmer, developed another screen reader called JAWS, which is one of the most widely used screen readers in recent years [61]. The screen reader can also be regarded as an interface between blind users and the operating system to convey digital information from various applications [26]. From the 2021 WebAim survey investigating screen reader use among around 1,500 respondents, 75.8% of respondents in total indicated the main reasons for using screen readers for their features and comfort use [13]. The survey also shows that 90% of respondents use mobile screen readers for their daily tasks [13]. Different types of

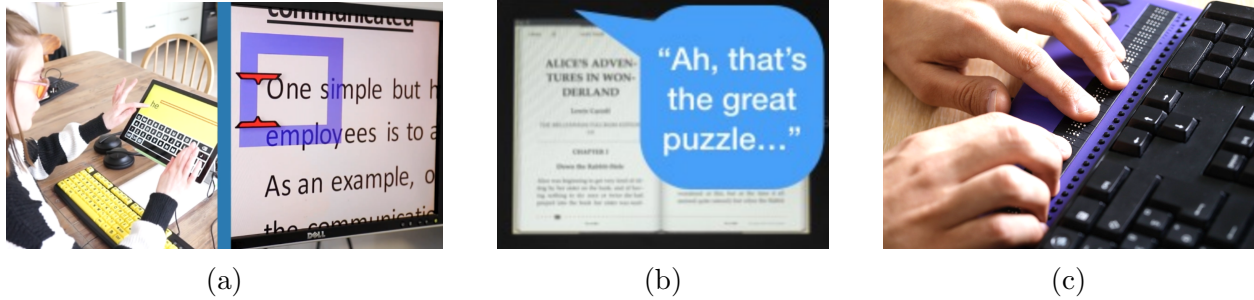


Figure 2.1: Examples of different types of screen readers. From left to right: (a) Desktop screen reader allows people to use keyboard shortcuts to control, and vocalizes digital content, (b) Mobile screen reader has similar functionalities to desktop screen readers, such as VoiceOver from iOS [87], (c) Refreshable Braille display can dynamically update Braille by raising its keys.

assistive technology are shown in 2.1.

When users start reading digital information on their devices, the screen reader will find any text or alt text for image description with top-down directions on documents and websites [26]. Screen readers can also be controlled with keyboard shortcuts for navigation through contents in a non-visual way [8, 10]. By using different scanning rules, users can read information by single characters, words, and lines [10]. A screen reader's main function is to read aloud the information on the screen as it is displayed on the screen. Auditory feedback from screen readers is the main source for people with visual impairment to receive and perceive digital information mostly [50]. Some screen readers support Braille output so that users can have information on a refreshable Braille display. This allows them to have an alternative way to utilize screen readers when having difficulties receiving auditory information [10, 26]. Recent releases of screen readers are compatible with applications in the workspace (e.g. Microsoft Word, Excel, email clients) as well as in daily life (Web browsers, music players, internet chat software), so people with visual impairments have to a certain extent equal access to digital information [8, 10].

Since the first invention of screen readers in the 1980s, desktop screen readers have been dominantly used among blind individuals [11, 26]. According to WebAim survey results,

Windows is the most used operating system by blind people (91.1%), and NVDA and JAWS on Windows are the most popular screen readers (84.4%) [13]. A number of previous research have taken the easier approach by focusing only on web browsing rather than enabling computer interfaces to the fullest extent possible [26, 31, 71]. The majority of non-visual web browsers are implemented as extensions to enhance the functionality of internet browsers [31]. Additionally, there are web-based screen readers that help increase accessibility for devices without the ability to download and install screen readers. However, both non-visual web browsers and web-based screen readers have limitations in providing the same extent of functionality as desktop-based screen readers [26].

Mobile screen readers are frequently used by people who are blind as well [13, 31]. The most well-known screen readers are VoiceOver from iOS and TalkBack from Android platform, as survey result shows 71.5% and 29.1% of respondents use those two mobile screen readers. The survey also shows that 90% of respondents use mobile screen readers for their daily tasks [13]. Different from desktop screen readers, mobile screen readers can assist blind users in performing several tasks, such as navigating their way and reading labels on objects in different places and occasions [31].

Screen readers allow blind people to use digital images accompanied by image descriptions. Image descriptions are seamlessly embedded in HTML documents, ensuring they are hidden from sighted users while offering significant information about images to blind individuals using screen readers [49, 54]. According to W3C, this is regarded as image accessibility and is listed as the most basic and first requirement for web accessibility [7]. Captions, alt-texts, and long descriptions are subsets of image descriptions that describe the content of an image so that it can be accessed and used [54]. Each of them provides different levels of image accessibility; for example, alt-texts are specifically embedded into tags in HTML documents, which are called “alt” attributes with a short description of images, while image descriptions directly describe what is in the image and attached in mostly the body of webpage and social

media posts [54, 74]. The alt-text is one of the most widely used representations of image accessibility, which was introduced in HTML 2.0 in the mid-to-late 1990s. Some commercial software, for instance, Microsoft Word and Adobe Acrobat, allow users to add alt-texts to images, which were mostly added by developers who have dealt with HTML documents in the past [49, 74].

While image description capabilities and standards have existed for decades, there are varying accounts as to how well digital media conform to these standards. For example, web accessibility standards and guidelines (WCAG) have been established and maintained by W3C since the early 1990s. In 1995, WCAG added alternative text in HTML 2.0 for the first time [24]. However, the conformance of digital media to these standards is still debated, with far less than 100% compliance. According to Guinness et al., image accessibility has improved from less than 40% to 72% among popular websites over a period of 12 years among popular websites since 2006 to 2018 [25, 51]. On the contrary, the use of alt-text in social media platforms has been found to be low, such as Twitter, where only 0.1% of posts contain alt-text, creating a huge gap in the experience of accessing information between sighted and blind users [49]. Additionally, a large number of webpages, documents, social websites, and applications provide alt-texts of low quality that do not comply with accessibility guidelines [32, 66, 74, 91].

2.2 Background: Digital Book Vendors and Formats

Digital books, also known as e-books, have changed the way we access and consume written content by transforming printed books into electronic versions. These e-books can be accessed through various devices, including standalone digital book readers, desktop computers, tablet PCs, and mobile phones [19, 75, 79, 88]. While some digital books are electronic copies of their printed counterparts, others exist solely in digital format without a corresponding

printed version. The advantages of digital books compared to printed books are possibly lower prices, comfortable book shopping, and increased title selection [79]. Moreover, digital books enhance the reading experience by providing features like easy bookmarking, quick annotation, and the ability to search for specific pages or information within the text [21]. Although digital books offer numerous benefits for people, a study has indicated that students showed lower comprehension levels on longer pages of digital books when compared to their printed counterparts due to the necessity of scrolling pages on digital devices [84].

2.2.1 Overview of the Digital Book Market and Its Growth in Recent Years

Digital book vendors are the main service providers for borrowing and purchasing electronic versions of books online. In the United States, notable digital book providers include Google Play Store, Amazon Kindle, and Barnes & Noble [3, 4]. Taking Google Play Books as an example, they offer a collection of over five million titles providing EPUB and PDF formats. With more and more vendors joining to provide digital books, in 2020, about 190 million digital copies were sold, compared to less than 100 million copies in 2010, which shows stable growth in the digital book market [92].

2.2.2 Audio Book Format

The first audiobook became available in 1932 when The American Foundation for the Blind established a recording studio for creating vinyl recordings of books [12]. Audiobooks were popularized by the broader population in the 1970s and 1980s with the invention of the audio cassette and Sony Walkman [85]. At the same time, audiobooks also arose as an educational tool for people with disabilities. Notably, prior research has highlighted the

benefits of audiobooks as a learning aid for students facing reading challenges like dyslexia [9, 73]. These studies suggest that audiobooks can effectively reduce the decoding process, allowing individuals to focus more on listening comprehension. Audiobooks have also proved invaluable for blind individuals due to their simplicity, affordability, and non-Braille option [89].

Initially, the term “audiobook” refers to a recording of book content narrated by humans, which is then converted into audio formats like MP3 and AAC [40]. Some earlier research expanded the notion of digital books to encompass audiobooks [60, 79]. However, for the purpose of this thesis, I will maintain the distinction between audiobooks—which are narrated by a human—and digital books read by the screen reader—which use a synthesized voice and provide fine-grained reading control to the reader.

2.2.3 Digital Book Format

Over the past 20 years, over 20 different file formats have been developed for digital books [5]. Among these formats, PDF and EPUB are the most popular file formats provided by digital book vendors today [3, 4, 60].

The PDF, or Portable Document Format, was developed in 1993 by Adobe. It contains various components, such as logical structuring elements and layers [2]. However, PDF still has a lot of usability and accessibility challenges (e.g. slow page loading, content disorientation) that have persisted since its inception two decades ago [77]. EPUB was adopted as the standard format of digital books by the International Digital Publishing Forum in 2011 and is the most widely accepted and supported format for digital book readers [68]. It is an XML-based digital book format with components, including HTML and images, that are interpreted by digital book readers, making its contents dynamically adaptable to the book reader[5]. The National Federation of the Blind recognized the potential of EPUB

as the future of digital book accessibility over a decade ago, especially due to its alignment with W3C's Web Content Accessibility Guidelines (WCAG) [70]. Recently, in 2023, W3C announced a new version of EPUB, version 3.3, which shows that EPUB is regularly maintained and supported by the organization [7].

While EPUB and PDF are the primary formats for digital books available online, the 2019 WebAim survey revealed that more than half (60.6%) of screen reader users preferred using Microsoft Word format over EPUB and PDF [13]. Additionally, 68.9% of respondents indicated that Word was the most accessible format they used [13].

2.2.4 Limitations on Digital Management Rights

Most digital books use encryption called Digital Right Management (DRM) [48, 58]. DRM is used to restrict access to copyrighted contents (e.g. music, books) with product keys and activation limits to prevent contents from being illegally copied and distributed [48]. Amazon and Adobe are the primary DRM providers in the digital book domain [2, 3]. Adobe also provides its own DRM protection as a third-party service to digital book vendors. For example, a book downloaded from the Google Play Store will be authenticated by Adobe's DRM server, which limits downloads to a maximum of 5 devices under the same user account.

DRM and its impact on accessibility are subject to ongoing debate [58, 94, 96]. For blind people, DRM may affect some of the functionalities of assistive technology—for instance, text-to-speech—or even create new accessibility barriers when they read and manage digital books. Fortunately, DRM laws have exemptions for people with disabilities, making it legal to decrypt or “crack” DRM protection for accessibility purposes, so long as the cracked digital book files are not distributed [96]. In 2021, the Librarian of Congress allowed developers and researchers to crack DRM protection for research purposes at educational institutions and organizations, which further loosened DRM restrictions and created new opportunities

for improving digital book accessibility [96].

2.3 Parent-Child Co-reading and Book Format

2.3.1 Co-reading: Printed Books

Co-reading between parents and their children has been widely reported to benefit the early development of the child [43, 72, 93]. A study conducted in 1988 in the Psychology field found that co-reading with children could provide parents with unique opportunities to model reading behavior and to engage in dialogic engagement during the reading process (e.g. posing additional questions outside of the story as a result of the dialog) [93]. Mol and Bus et al. reported that early print exposure to children and preschool children improved their reading comprehension, oral language, spelling, and technical reading skills from a meta-analysis of 99 studies on children's leisure time reading in 2011 [72]. It is reported that printed books are considered to be an important activity for parents and children to build familial bonds between them [41]. Recent research has argued that co-reading is not only an activity for children's development but also should be regarded as an intimate and social process for both parents and children [57, 87]. With the more inclusive definition, researchers gain more opportunities to explore co-reading as an interdependent process between parents and children, as well as between those with and without disabilities.

2.3.2 Co-reading: Digital Books

Many studies in the psychology and education fields have warned that the transition from printed books to digital books may harm the development of children's literacy skills due to the impact of emerging interactive technologies [44, 53, 69]. According to a survey study

conducted of 2,243 parents, many parents used digital books for entertaining and occupying their children rather than for learning and developmental purposes [41]. They also expressed concerns about electronic devices due to matter that the blue light emitted from screens will lead to sleep disturbances for children, as co-reading usually happens before children's bedtime [41]. The appropriateness of digital books for co-reading is still a matter of debate, as it is unclear as to what effect digital books may have on the development of children [41, 57, 80]. In the HCI community, many researchers have attempted to improve reading between parents and their children or even replace the parent's role through the use of technologies and devices [35, 80, 90, 97]. For instance, Zhang et al. designed and developed an AI-enabled StoryBuddy system, which generates appropriate dialogic questions about the story without parent intervention [97].

2.3.3 Blind Parents and (Blind) Children

When it comes to co-reading, which includes people with visual impairments, researchers from the HCI and the Education domains have mainly targeted children with visual impairments (CWVI), not blind parents [56, 78, 86]. In addition to this, there has never been any research on blind parents reading with their children who are blind. Several researchers have focused on the use of tactile books because tactile books can provide an additional layer of three-dimensional information to assist CWVIs with the ability to feel and learn about the environment around them as it unfolds [56, 78, 86]. While there are many works investigating co-reading interaction between sighted parents and children, only one research focused on co-reading between blind parents and children. According to Storer et al., they analyzed 497 unique threads from the Blind Parent Forum (BPF) and identified various co-reading strategies that blind parents use with their sighted children, as well as identifying several challenges [87]. Yet, there is still a lack of research about co-reading between blind parents and sighted children. Given this literature gap, our work can contribute to understanding

the co-reading practices and preferences of blind parents with sighted children as regards digital books.

2.4 Digital Reading and Blindness

2.4.1 Braille Reading

Over two centuries have passed since Louis Braille, who had been blind since the age of 5, developed the Braille dot-style tactile system that remains in use by blind individuals today [14]. It wasn't until 1909 that this system was formally acknowledged as the primary reading medium for blind users in the U.S. [15]. Beyond enabling PWVI to read and write, Braille has been associated with positive outcomes in their lives. It is reported that those who read Braille weekly have a greater chance of being employed and earning more than those who do not read Braille every week, according to a 2015 survey of over 1,000 legally blind adults [22]. Moreover, a study of 443 legally blind adults also discovered that Braille readers were more satisfied with their lives and felt more self-esteem than those who had never learned it [83].

However, recent research indicates a decline in Braille literacy due to the increasing prevalence of electronic devices and assistive software, such as screen readers [39, 45, 81]. The National Federation of the Blind (NFB), the largest organization of blind individuals in the USA, refers to this decline as the “Braille literacy crisis” and continues to advocate for increased Braille education for blind children and adults [14]. Despite this tension between digital and analog reading technologies, PWVI regularly uses text-to-speech AIs, like screen readers, to read digital texts. In addition, devices supporting Braille reading and writing of electronic text, including the refreshable Braille display, are often prohibitively expensive for PWVI, leading them to use cheaper conventional QWERTY keyboards instead [39].

Despite the potential adverse effects of assistive technology on Braille literacy, researchers have actively explored ways to combine the benefits of assistive technology with Braille for PWVI [18, 45, 59, 67, 76]. In 2010, Kumar et al. developed an application to convert mobile SNS messages into Braille script using special symbols to allow PWVI to read Braille via mobile devices [59]. Tangible user interfaces have also been leveraged as mediums for PWVI, leading to the creation of innovative tools such as HoliBraille and SingleTapBraille keyboard, specifically designed to enhance interaction through multimodalities on touch screens [18, 45, 76]. Furthermore, researchers have developed prototypes for Braille use on smartwatches, offering a notable approach to incorporating Braille into wearable technology [67]. Another crucial target group has been children with visual impairments, as researchers have designed BrailleBlocks, a type of building block that facilitates storytelling through Braille, effectively enhancing Braille education for young learners [46, 47].

2.4.2 Assistive Technologies for Reading

Apart from assistive technologies enabling Braille use in electronic devices, numerous research studies have focused on enhancing existing features on digital platforms to offer more opportunities for PWVI in digital reading [21, 30, 62, 63, 65, 82]. Shin et al. developed an accessible digital book reader that allows PWVI to read the same content as sighted users, with customized UI and advanced functions for navigating pages (e.g., logical unit reading) [82]. Other researchers directed their attention towards the digital book format itself, seeking to improve its interactivity and usability for PWVI. Leporini et al. improved the interactivity and usability of EPUB, which still has the accessibility issues observed via screen readers, by integrating easy navigation and personalization [21, 65]. They also proposed a tool with a different approach, which can convert PDF files into the EPUB file format with more suitable and accessible elements for students with visual impairment [30]. Furthermore, specific research has targeted comic books for PWVI, recognizing that comics, which heavily rely on

images, require detailed image descriptions for PWVI to comprehend their contents [62, 63]. Similarly, our work has centered on digital children's books. These books also contain images and limited text but differ in their use of more abstract and cartoon-like pictures compared to other types of books.

2.4.3 Mixed-ability Reading

Research on assistive technology for PWVI has primarily concentrated on examining individual use scenarios [18, 21, 45, 59, 65, 67, 76], with some notable exceptions [23, 28]. Branham and Kane explored how accessibility is produced in the homes of PWVI who live with sighted housemates, coining the phrase “collaborative accessibility” to describe how accessibility sometimes requires cross-ability collaboration and how assistive technologies might obstruct familial bonding opportunities [28]. Furthermore, Bennett et al. proposed the novel concept of “Interdependence,” which emphasizes the need not only to target PWVI as individual consumers of assistive technology applications but also to consider the relationships people have with various contexts— including their disabilities, the use of devices, and interactions with others possessing different abilities—to ensure more inclusive ability-based design [23]. Several studies have since begun to discuss accessibility challenges in “mixed-ability” settings, such as collaborative workspaces [29], collaborative in-door navigation [95], collaborative hybrid meetings [17], and collaborative writing activities [38]. Following a similar line of investigation, I explored how interactive technology, specifically digital children's books, can be harnessed to support blind parents in collaborative settings with their sighted children. I look forward to contributing more inclusive experiences for blind parents within a broader social context.

Chapter 3

Method

In this chapter, I summarize the methodology used for answering research questions. This chapter is divided into two parts, corresponding to my two research questions: (1) a content analysis of digital children's books and (2) an interview study with five blind parents.

3.1 Book Content Analysis Design and Analysis Process

The first phase of this research project involves a book content analysis that aims to gain a preparatory understanding of the current state of digital children's books. I used the convergent mixed method approach for this book content analysis study [33, 37, 42]. Quantitative and qualitative data were collected to understand the current accessibility state of digital children's books. I analyzed books collected from an online book platform, focusing on accessibility issues within those books. To measure how accessible the books were, a data collection table was created that included metadata that would be collected from the books to measure their accessibility level. The Table has been divided into three main sections.

Book Metadata	E-book Accessibility	Image Accessibility
Book Title	Table of Contents	Image Counts (Ace)
Publisher	Appropriate Table of Contents	Image Counts (Manual)
Online Vendor	Paragraphs	Book Cover Alt-text
Book Topic	Page List	Alt-text Tag Counts
Pages (On Purchase)	Page Numbers	Empty Alt-text Counts
Pages (Main Content)	Adjustable Font Size	Level of Alt-text
Pages (Total)	Proper Text Alignment (ADE)	Appropriate Alt-text
Explanation of Page Discrepancy	Proper Text Alignment (Google)	Contextual Information

Table 3.1: Book accessibility measurement

In the first part, I provide basic book information obtained from the purchase page and loaded into a digital book reader without further exploration. The second part is digital book accessibility, which involves looking at content such as navigation and text alignment in digital books. For quantitative analysis of accessibility, the Ace accessibility checking tool [1] was used to provide a brief report on the books' accessibility level. A third measurement considers how well images are accessible to blind parents. To accomplish this, it is necessary to review the alt-text and qualitative information the book content provides. Using these measurements, we can gain valuable insights into the accessibility of digital children's books for blind parents, enabling us to identify areas of improvement moving forward. As the interview protocol in phase one, I collected three books for the pilot study and iterated the metadata that should be collected. The detailed metadata collection information is in Table 3.1.

A strategy for selecting the type of digital book format and which books to collect was designed to ensure that the collected digital children's books were representative and meaningful for the study. I selected the EPUB format to collect for this study, which EPUB was explained to be accessible in the background of this study. I collected popular and highly recommended children's books from authoritative sources, including the New York Times, NPR, and Penguin for the book collection. Moreover, books were also collected from the Social Justice and African-American book lists to highlight the importance of accessibility and inclusivity in children's literature as well as the importance of inclusivity in children's

literature. Iteratively, two researchers collected book information.

As a result of collecting book information from authoritative lists and considering the needs of blind parents, I developed a sampling rationale for the book collection. According to the interview study, blind parents use book platforms explicitly designed for people with disabilities and visual impairments, such as Bookshare, Seedlings, and Bard. As a result of comparing several commercial book platforms, I decided to use Google Play Books as a data collection source. Over 5 million titles are available on the platform, which is more than all of the titles from disability-specific platforms. Additionally, Google Play Books has cross-platform applications, which can be accessed on mainstream devices (as opposed to special-purpose assistive devices). It should also be noted that Google Play Books is available in both EPUB and PDF formats, which aligns with the rationale for the decision to choose a digital format mentioned earlier. Due to this information, I decided to purchase the book that matches the condition that can be purchased on Google Play Books, but not on Seedlings, Bookshare, or Bard. Besides the book platforms for disabilities, I wanted to know how much accessibility they could obtain from books that they purchased on other book platforms such as Google. Specifically, because some books only contain images, I checked the sample of each collected book to ensure the book was an appropriate picture book.

We collected information about 120 children's books from several authoritative lists (i.e. the New York Times from 2015 to 2022, NPR 100 Children's Books list), but only 14 of these 120 children's books we analyzed were available in digital eBook format met the criteria that they could be purchased via Google Books, whereas they were not available via BARD, Seedlings, or Bookshare.

Based on the strategy and rationale for the data collection, I collected 14 digital children's books in EPUB format in total from Google Play Books. The sampling flow is shown in Figure 3.1. The sample of books was published between September 2014 and May 2021,

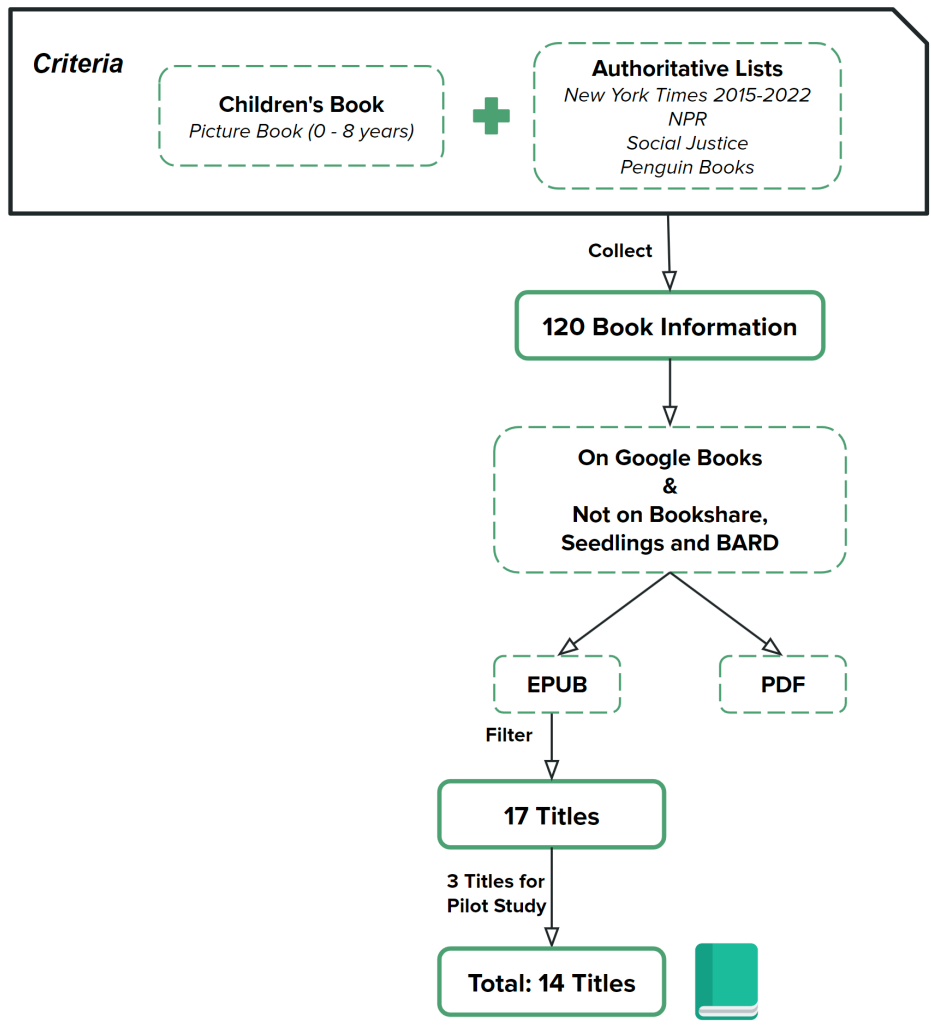


Figure 3.1: The book sampling flow

which covers the recent period for books for children. In our sample, Penguin Books and Simon and Schuster are the two major publishers of children's books. All books met EPUB file format requirements. Each book encryption is legally cracked with the DeDRM tool [6] for accessibility research purposes without distributing outside the lab. Book information and analysis are uploaded on Google Drive in a spreadsheet to keep the latest update. After removing encryption on digital books, I used three processes to analyze each book manually. First, I achieved basic information (i.e., book title, publisher, page count) by importing the text into Adobe Digital Edition. Second, the Ace accessibility checking tool exported the book's metadata and quantitative data. Lastly, the Calibre EPUB editor was used to check qualitative data and some quantitative data, which was not detected by the Ace accessibility checking tool. Each book took approximately 50 minutes to finish the whole analysis process.

3.2 Interview Study Design and Protocol

To understand blind parents' perspectives on using digital books for co-reading with their sighted children, I recruited five blind participants and conducted individual qualitative interviews. The interviews aimed to explore several aspects of participants' experiences with digital books. First, I asked participants to describe their use of digital books for personal reading and co-reading with their children. Second, I asked them to describe the factors influencing their decisions in selecting the device and format for personal reading and co-reading with their children. Third, I asked them to tell the typical experience of reading with their children, including preparation before reading and difficulties encountered during reading. Fourth, we discussed reasons for choosing to read or not read digital books with their children. Finally, we discussed future opportunities regarding digital books, such as what issues and accessibility settings they want to be added to digital books to support better reading together.

We conducted semi-structured interviews to let participants express themselves without an order of interview questions. We allowed participants to talk more about their experience, and we extracted some information that could answer our expectations. A pilot interview was conducted with a blind parent and digital book author specializing in accessibility. The pilot study involved testing the interview questions and making necessary adjustments to improve clarity and relevance. Based on feedback from the pilot study, 18 questions were finalized and used in the subsequent interviews with blind parents (see Appendix A). The questions were created to gather detailed descriptions of participants' experiences and viewpoints towards using digital books for co-reading with their sighted children. Furthermore, the open-ended questions allowed for additional probing to ensure a thorough exploration of reading experiences.

With careful adjustments, the finalized interview protocol includes several detailed sessions, including the recording consent. In addition to recording data, individual notes were taken for each participant, recording key points and essential notes from each interview. These notes will be used to guide further qualitative thematic analysis.

After the introduction, the following session of the interview protocol was focused on the "Use of digital books." The purpose of these questions is to gain insights into the overall experiences of blind parents with digital books and to understand how these experiences may influence their decisions about and differ from reading digital books with their sighted children. Specifically, I focused on their preferred platforms and file types to read, their main accessibility challenges during reading, and their overall experience. Firstly, participants were asked to describe their experience with digital books, including whether they read digital books and their preferred device. In addition, they were asked about their favorite digital book reader applications and the types of digital file formats they use. They were also asked how they choose which devices, file types, and application combinations to use for reading. During this session, participants were encouraged to share any accessibility

issues they encountered while reading digital books. Furthermore, I expanded the question to explore whether it was typical for blind parents to read digital books. Participants were asked to share their general practices of reading digital books.

In the second section of the interview protocol, I focused on participants' experiences of reading books with their children. I asked the same questions for digital books for personal use, adding questions to inquire about the frequency of reading books with their children and their perspectives on the difference between reading to themselves and reading to their children. These questions were included to thoroughly understand the participants' experiences and incorporate their views into my analysis.

The last session asked blind parents about “Opportunities for digital children's books”. The purpose of this session was to seek the possibility of digital book use in the co-reading process between blind parents and sighted children in the future. We seek blind parents' concerns, the functionalities they need, and their expectations of digital books. The session comprises questions about detailed categories concerning accessibility issues, including image, navigation, device, and general accessibility of digital books. In particular, participants were asked about the importance of images in books and how they acquire information about images. I asked this question to get more information regarding their external assistance for reading the book and their perceptions about images that they cannot see but that their sighted children can see. The final question I asked the participants was what they expected from digital children's books and if they were interested in using them with their children. As part of my interview, I asked them about their opinions regarding the possibility of using a voice assistant to recognize images, control navigation with ease, and include image recognition. The purpose of this question was to better understand their willingness to use the latest technology to make digital children's books more accessible and enjoyable for both them and their children. The finalized interview protocol is attached in Appendix A, with the order of each interview session.

3.3 Interview Data Collection and Analysis

We opted to conduct the interviews remotely via Zoom meetings Due to the COVID-19 pandemic and our target participants being blind parents. Conducting the interviews remotely allowed us to accommodate the mobility limitations of blind parents and make them feel more comfortable participating in the study. Additionally, blind parents are a minority group in different time zones and cities, making it challenging to conduct in-person interviews. By using Zoom, we connected with participants from other places and conducted the interviews at times that were convenient for them. Another factor we considered was safety due to the COVID-19 pandemic at the time of this interview study. Conducting interviews in person may have posed a risk of COVID-19 infection and personal safety during the interview. Overall, using Zoom meetings provided a convenient, accessible, and safe way to conduct interviews with blind parents. The study is approved by IRB.

Participants were recruited through online posts on websites and social media platforms for blind parents of young children. To ensure anonymity, the website and the platform will be referred to as the Blind Parent Forum (BPF). To be eligible for the study, participants had to be 18 years old or older, legally blind, and have at least one sighted child between the ages of 2 and 8. For those interested in participating, we asked them to contact the researcher by email or phone to express their interest in participating in the study. Before the study, participants were given a brief explanation of the participation procedures and the purpose of the study. All participants gave their informed consent before participating in the study. Considering the characteristics of the online platform, the consent forms for the interviews were sent through both the email and direct message features provided by the forum website.

To better understand the topics covered in our interview study, we used thematic analysis [27]. Once the interview data were collected, I extracted a first round of possible theme codes based on transcriptions from Zoom's service. By iterating through the interview data with

Participant	Sex	Age	Sight Status of House Member	Years of Being Blind
P0	Female	41	Sighted Husband	20
P1	Male	35	Sighted Fiance	3
P2	Female	35	Sighted Mother	25
P3	Female	39	Sighted Husband	Since Birth
P4	Female	38	Blind Husband	30

Participant	Use of Braille	Braille Proficiency	Children	Children's Age
P0	Yes	Level 1	1	2 / 4.5
P1	Yes	Level 2	1	2 / 6
P2	Yes	Level 2	3	2 (twin)/ 9
P3	Yes	Level 2	2	2.5
P4	Yes	Level 1	2	1.5

Table 3.2: Demographic information

inducing coding, I generated more subcodes for combining those codes to higher levels of themes. After generating thematic codes, each subcode was composed of direct participant quotes.

Out of the participants contacted, 8 participants responded, and 5 participants who met the eligibility criteria accepted the interview invitation. The interviews were conducted remotely with two researchers via Zoom meetings. Additionally, the audio was recorded for internal research use and completely transcribed by Zoom transcription service. The average interview lasted 60 minutes, ranging from 45 to 90 minutes. Participants were paid \$40 per hour with an Amazon gift card via email. With the pre-screening email, I asked participants for demographic information and sent follow-up emails after gaining insights from thematic analysis to ask for additional information. I define Braille proficiency with two levels in this study because participants did not report their level of Braille reading (i.e., contracted and uncontracted): Level 1 means they know how to read Braille but do not prefer to use it due to lack of proficiency and confidence; Level 2 means they are experts in Braille reading and prefer to use Braille. The demographic information of participants is detailed in Table 3.2.

Chapter 4

Findings

In this chapter, I summarized the findings from our analyzed data. I analyzed the content analysis of 14 digital children's books and interviews with 5 blind parents to explore research questions. Our analysis revealed that none of the digital children's books from our sample meet official accessibility guidelines for digital books, particularly in terms of image accessibility for both blind parents and their sighted children. Moreover, all blind parents in our sample expressed their reluctance to use digital children's books when co-reading with their sighted children. This study identified several factors that contributed to their decision not to use digital books. These factors included the lack of accessibility features, the difficulty in navigating the books, and the preference for physical books. I included representative book content examples and detailed thematic codes with authentic direct quotes from participants to provide a better understanding of our findings below. The chapter is divided into two major sections: findings from book content analysis and interview analysis.

4.1 Research Question 1: What Is the Current State of Digital Children's Book Accessibility?

4.1.1 Overall Book Accessibility Compliance: Digital Book Does Not Meet the Official Accessibility Requirements

We found a lack of adherence to official accessibility requirements among the digital children's books in our sample based on Ace Accessibility Checker [1]. Following industry standards and guidelines [7, 36] for accessibility is the only way to ensure that readers have a consistent, accessible reading experience. Unfortunately, none of the digital children's books in our sample perfectly met the official accessibility requirements, indicating a widespread issue that needs to be addressed by publishers and book providers in the children's book industry. Ace Accessibility Checker measures the level of accessibility violations on a scale of minor, moderate, serious, and critical. I divided the violation count into more than serious and total to show the ratio of the accessibility guideline violations. There was 38.5 missing accessibility metadata across the 14 books, with a range of 4 to 60 violations on average. These violations ranged from missing alt-text descriptions for images to improper labeling of headings and links, which can significantly impair the reading experience for visually impaired users. Considering the growing demand for digital reading materials, the failure to comply with accessibility standards is particularly concerning. Violation information is detailed in Table 4.1

4.1.2 Metadata Inaccuracies

Inaccuracies in book metadata can be a problem for parents of blind children who rely on accurate page counts to navigate through a digital book during reading time. As we found

Book Title	ISBN	More Than Serious	Total
You Matter	9781534421707	41	51
A Fine Dessert	9780375987717	15	16
The Snowman	9780141361017	5	8
Freedom Over Me: Eleven Slaves	9781481456913	60	63
Hey, Boy	9781481471022	52	55
Funnybones	9780241334683	44	48
Ayobami and the Names of the Animals	9788416733019	44	48
Meg and Mog	9780241384916	47	50
Good Boy	9781481499071	48	51
Hold Hands	9781250266354	26	30
A Story about Afiya	9781913747145	40	44
Our Little Kitchen	9781683359784	54	57
We Found a Hat	9781536220735	59	62
We All Play	9781771646086	4	7

Table 4.1: Violation count from Ace Accessibility Checker

in our analysis, most of the sampled books did not have actual page counts that matched the page count shown on the purchase page, which can be a frustrating and confusing experience for users. The actual page count refers to the number of pages that are actually present in the digital book file itself. On the purchase page of the book, there is also a number that indicates how many pages there are in the book. Only two books in our sample had consistent page counts. Whenever the actual page count exceeds the purchase information, the actual content may include more pages, such as a table of contents and appendices, which are regarded as front-matter elements. Some of these situations have pages marked with Roman numerals that are recognized as the actual page count. In the case of Roman numerals, say, the book is marked as 40 pages on the purchase page, but when read, it is 45 pages, and 5 pages are marked with Roman numerals. In addition to that, there are some pages that are duplicated, so the actual page count is higher than the page count on the purchase page.

When the actual page count is less than the page count on purchase information, apart from the situations above, we cannot tell which pages are missing. Consequently, there is a mismatch between page counts on actual pages and those on the purchase page.

4.1.3 Potential Navigation Challenges for Blind Parents

There is no unified standard for the table of contents in the books, which is an important aspect for blind people when navigating digital books as it is their primary way of navigating them. It is common for the table of contents to include chapter titles in digital literature to allow readers to navigate within the book; however, in digital children's books, this isn't the case, because there is usually only one story for children included in the book. The majority of the pages of the book are illustrated with a few text paragraphs, so there is no appropriate table of contents, as most of the pages have illustrations instead of text. Tables of contents are included in the majority (93.3%) of sample books. A title page, book cover, and copyright page are common in digital children's books, but there are 6 books (12.9%) that do not include all that information (e.g. only contain the title page). Our sample also contains a page called "Start reading page" page. There are five books (35.7%) in the table of contents, of which a Start reading page is present. Generally, the start reading page is the first page on which the main content begins. Start reading pages are referred to by a variety of names, such as "Start content page", "First page of text", or even by the title of the book itself (e.g. "Meg and Mog", "We found a hat").

Another item that we could rarely find in the table of contents is the page number list as a replacement for chapter header navigation, which allows users to navigate to any page in the table of contents they want. There is one serious issue that we found from this study concerning navigation accessibility, which is that when we are using the built-in navigation feature of the digital book reader to navigate to a specific page, the reader does not navigate to the same page when we click on the same page number in the table of contents.

4.1.4 Visibility Issues for Sighted Children

The results of our study indicated that some visibility problems in digital books might affect the quality of co-reading experiences for sighted children. Depending on the reader, there are different default settings that apply to their CSS settings, meaning that different styles of HTML texts can be configured for different digital books, such as text colors and alignments. As we opened the books in other digital book readers, we found that there was an issue with color contrast between text and background, affecting the readability of the text, especially in light colors (see Figure 4.1). In Figure 4.1, we can see that even for sighted people, the gray color font is difficult to read when we open it in the locally installed digital reader on the desktop. In the case of visually impaired parents, it can be difficult for them to check what color settings are already set in the configuration file, and to modify them accordingly.

There are some instances where text alignment displays abnormally in different readers. The digital book is properly displayed in Google's own digital book reader, but when opened in other digital readers, overlapping text and large text are apparent (see Figure 4.2). The ability to adjust text size in a digital book reader should be one of the most basic features that the reader has, particularly for large texts. The reason might be the fact that the texts in the book aren't exactly embedded into the exact HTML tag, so the readers are unable to detect the text if it is in the book and not able to adjust the size of the text as they can in other books. Alternatively, there is a possibility that some texts are embedded in the image itself as a result of the fact that most books are pictures, and thus, the book providers did not extract the text from the images, which caused this accessibility issue to occur.

4.1.5 Image Accessibility for Blind Parents

As part of our research, we also discovered how accessible images are in digital children's books for blind parents. This is critical for blind parents when they act as the main book

"Good night, Froggy!" said Mr. Owl, sitting on a branch.



Figure 4.1: Grey font with white background, worse on deep-colored backgrounds



(a)

Entirely unrecognizable,

(b)

Figure 4.2: Words crowded in the sentence. Left: Uncertain text alignment; Right: Overlapping texts

reader in a co-reading process with their children. In order to be able to detect alt texts in EPUB files, Ace Accessibility Checker detects three different types (Alt-text attribute / figcaption / aria-described) of alt text. All of those can be included in the description of images in the digital book guidelines. Our samples, however, do not have any appropriate image descriptions for each image. Our sample books show that, on average, there are 39 images in the books that need alt text in order to assist blind parents in understanding the images in the books. However, Ace is only able to detect an average of 9 alt text HTML tags when it is used. Because it is possible that the book EPUB data might contain alt text tags that are not detected, I manually opened the EPUB data with the Calibre EPUB editor, which, on average found 32 alt text tags in the book. In spite of the official tool for checking digital book accessibility, there is a problem: even the tool is unable to recognize the alt text tags.

It should be noted that even though the alt text tags were not detected as expected, 3 of the books (20%) actually contained alt texts. Those books, however, only have “Background image” embedded in the alt text, which is insufficient for image description. It is also worth noting that with the exception of those books with inappropriate alt-texts above, all of the alt-texts for all of the books are either empty or do not contain the HTML image tags that can be detected by Ace Accessibility Checker, as we discovered in the above example. Furthermore, since book covers are displayed before people actually read a book, these are also important resources to help people understand what a book is about before they even begin to read it. Nonetheless, we have not been able to find any exact description of an image for a book cover in our sample of book covers. Whenever blind parents want to know which image is on the cover of the book they have purchased, in their screen reader, they will only be able to see “Background image”, as the screen reader only tells them what the image is.

Blind parents can obtain some information about an image from contextual information

provided in a book, such as story texts, even if there is no alt text in the book, but they are still limited to obtaining comprehensive descriptions of images from this information. If there is no good description of the images in a book, blind parents will be unable to get any information from it. There are usually double-sided pages in a children's book, meaning that the images and contextual information are on both sides of the page, so children and their parents will need to read both pages together in order to understand the story fully. In fact, it is possible to consider a double page to be a single page since both of them share the information of context on both pages. It is, therefore, of great benefit to blind parents, if they have books that have been scanned from double-sided pages into single-sided pages so they can read them easily. However, only one book out of our sample (7.1%) has been scanned onto one page after both pages are scanned onto a single page. It is possible to display the content using different book readers that offer the option of selecting a double-page layout or a single-page layout, depending on how the pages are arranged. For example, when a double-page book is scanned and converted into a double-page in a book reader, both sides of the page can be displayed in one view at the same time, which has the same functionality as if it had been scanned into a double-page. However, this method is only useful for sighted individuals because blind parents cannot read with their sight. It is still important for blind parents to understand the context of both pages through alt-text information on both pages.

4.2 Research Question 2: Do Blind Parents Use Digital Books to Co-read with Their Children? Why or Why Not?

4.2.1 Physical Books and Visuals Are Essential

Prefer Braille Dual Vision Books

In our study of blind parents, we found that most would prefer reading paper books over digital books with their sighted children. All of our participants reported that they have tried reading with their children once or more times before. The blind parents choose to read twin-vision books to their children, regardless of whether or not they have achieved a certain level of braille proficiency.

Nevertheless, this choice is not because blind parents cannot read digital books. The majority of blind parents (P0, P1, P2, P3) have used digital books for personal reading, professional development, and leisure reading. Participants expressed that they would use a screen reader on a mobile device (e.g. VoiceOver on Apple iPhones, TalkBack on Android phones), on a computer (e.g. JAWS), or on an Amazon Kindle that comes with text-to-speech built-in if a book doesn't require a great deal of effort for them to read (e.g., a leisure book). Instead, if they had to read a difficult book (e.g., a textbook), they would download the book and use the Braille Display.

P0: "I read everything on my phone; I mean, I read on the computer, but not my books like I have the Bard app and Audible on my phone."

However, there is an exception that P4 usually enjoys reading on her own with an audiobook

as her personal reading method. In spite of the fact that she is a slow and late Braille reader, she still prefers to give her children twin-vision books to read.

P4: "I primarily use Bard audiobooks, either on my phone using the Bard application... I read a lot. Primarily, when I'm reading Braille, it's usually for my kids. So I don't read Braille [for myself]. I'm not proficient enough in Braille to be able to read like, you know, a 300-page chapter book."

Avoid Digital Devices

Participants (P2, P3, P4) expressed concerns about their children being exposed to a digital device at a very young age when they are still developing their learning capabilities. P2 mentioned that children will inevitably start to use digital devices in the future. For this reason, she is hoping that she will be able to avoid digital devices as much as possible with her children in the future. Even P3 has not tried to read digital books with her children, and she feels that there is no reason for her children to get familiar with digital devices if they don't need to at the moment. Reading digital books to their children instead of physical books also leads blind parents to feel "guilty" and frustrated as a result, as they feel that they are not responsible for their children. As P4 says:

P4: "But I also just felt a little bit guilty about it being on a screen. So that was sort of my own perception. Now my kids are on screens a little bit more. This was kind of the early days when my daughter was more of a toddler, and there was a book we wanted to read. So I'm like, oh, I'll just find it this way, and I just felt kind of clumsy with it."

Tactility and Visuals Are Educational

Blind parents use physical books rather than digital books for co-reading activities because physical books provide children with the opportunity to interact with tangible elements. P2 mentioned that the unique characteristic of physical books is the ability to touch and feel them, whereas digital books do not have any tangible elements; they are merely pictures and text on a page. For this reason, P0 chooses only physical books to read with her children, even though she is able to buy Braille books for the convenience of reading them.

P0: "I know I can order a lot of other hard copy books from other places where I use braille. But I wouldn't say that I read books that way. Because then it wouldn't be any fair for her, because she wouldn't be able to see anything."

In addition, P3 described the benefit of having physical books with a tactile feel. Using this kind of tactility with tangible elements, children can learn about the logical sequence of events in an object's story if they see images, plots, and physical elements intertwined together to demonstrate the logical sequence of events:

P3: "They can see pictures and partially so they can see how stories are physically put together. So that you understand 'Okay, there's a cover, there's a beginning, a middle, and an end to be able to start word recognition' is a lot of it. And just you know, having that physical that it's not on a screen."

Tactility and Visuals Keep Children's Attention

Children's attention is one of the most important reasons children cannot get involved in co-reading with blind parents (P0, P2). Our study found that digital books, audiobooks, and spoken stories by blind parents had limitations when it came to attracting children's

attention. As P2 mentioned in our previous conversation, she had tried using Amazon Kindle to read with his daughter a long time ago and was not able to keep her attention as the device did not provide any brightness or color to keep her interested. This is because Amazon Kindle is an e-ink display digital book reader that provides only white and black colors and is optimized for displaying text [52]. Similarly, P0 uses her voice assistant as an alternative way of reading books to her children in an alternative way to reading:

P0: “We have a computer in them in the living room, and Alexa and the baby's room. I try to do the audiobooks through Alexa, or whatever like the little kids' stories. Yeah, she didn't care. She ran away.”

Even though she tried telling children's stories from children's books by herself, she did not seem to be able to make them as appealing for them as physical books do.

P0: “I try to tell her stories all the time, and she just was like ‘Okay, there's not anything for me to play with touching, so I'm not listening to you anymore’. I love the fact that she loves all of her hard copy books, even though I can't always be involved with the hard copy because I don't know it's on every single page like I don't know what the picture is.”

Challenges with Braille Twin-Vision Books

Blind parents face challenges when reading Twin-Vision books with their children because of inaccessible images. Although most blind parents prefer Twin-Vision books over single-vision books, that doesn't mean that those books are the most appropriate choices for blind parents to read with their children. Due to the lack of image descriptions in physical books, blind people have difficulty understanding and recognizing visual elements. Exceptionally, P3 once

had a braille book that provided image descriptions – which is unusual in braille books - and hopes to have more such books in the future. According to some of the blind parents (P2, P4), they do not care about image accessibility when they are reading to themselves, but it becomes very important when they are reading to their children.

One of the factors that contribute to the challenges that blind parents face when using dual-vision books is their proficiency in Braille. As a Braille learner who is late in the process of learning the language, P2 feels frustrated when her children do not pay attention to her storytelling because she speaks so slowly,

P2: “I got they (other blind parents) will be having it read it by ear that repeating what it says out loud. But there are lots as frustrating that my daughter thinks I'm going too slow, takes the book, and runs off with it from my lap.”

4.2.2 Digital Books Are Not Appropriate

Lack of Intimacy and Connection Support

As co-reading helps with bonding intimacy between blind parents and their children, blind parents express that digital books often fall short in supporting the same level of closeness and connection as printed books do. When blind parents opt to read digital books, they are required to rely on audiobooks or other assistive technologies, such as screen readers or voice assistants. Unfortunately, this reliance on technology can result in children losing their attention to the book, as supported by previous findings. Consequently, blind parents have no idea of recapturing their children's focus on reading, which may not effectively nurture the desired sense of intimacy between parents and children. P4 mentioned that she wants to read in her own voice, without being read by a voice assistant or screen reader with a machinery voice. She believes that reading her own voice to her children is the responsibility

of being a mother:

P4: "I would really like to be able to read to my kids like it's one of those things just as a mom that I still kind of get hard on myself about. There's just something about reading to my kids that feels very like, that's my job. I love reading, so that's kind of my own internal stuff that I have."

Images are inaccessible

In reading with children, blind parents (P2, P3, P4) emphasize the importance of image accessibility. It is interesting to note that blind parents do not seem to care whether or not the level of image accessibility in their personal reading contains any alt texts, even if the images have no actual descriptions at all. As P4 pointed out, since their children are sighted, good image accessibility allows blind parents to be able to interact with their children more when reading their books. P2 states in a similar way,

P2: "I don't think about images unless it's a kids' book. Images are super important because my kids are sighted. I want them to be able to have the full experience. For them, it's super duper important."

Blind parents can use the image description to assist them in recognizing objects if a child describes a picture incorrectly, or if they are correct on what they described. There may not be enough language skills, knowledge, and recognition skills in children in their early stages of development. Thus, image descriptions can assist blind parents in guiding their children and teaching them the correct information and description that is necessary. According to P3, as an example,

P3: "Image descriptions (are needed), so that when I asked my daughter what's

in the picture, and she says 3 pink bunnies and a blue ball, but it's actually 3 pink bunnies and a hat (on the actual image), I can say 'No, look again, there are 3 bunnies, but it is a hat, not a ball'."

The blind parents (P3, P4), however, did not have digital children's books with image descriptions to support their co-reading experience with their children. When P4 discussed her experience reading digital books with her children, she said there were no image descriptions to be seen when she swiped between the pages in the book she chose. There was an exception in that they did include some image descriptions that are appropriate and distinguishable; P4 says,

P4: "Some kids' books actually have a little bit of a description of the picture. There's one that my daughter just got about the book 'Playing with clay', the book says 'It was clay until I rolled it', and the image description says 'Picture of a snake', so it captures the picture. Not all the books do that. A lot of them don't. And (image descriptions) didn't indicate any way, shape, or form."

We could also see this phenomenon when we analyzed the content of the digital children's books in our sample and found that none of them met the condition that they contained appropriate descriptions of the images. P3 believes that if the book format is one of a digital book, then there is never any image description at all included in the book. As she says,

P3: "None of those pictures are ever described so if it's an ebook graphic, I'm just kind of hanging out there and obviously audiobooks. In audiobooks, I'm not annoyed that they don't describe it; if it's in an ebook, there is no accessibility. None of those are ever described."

Technology Fails

There is some awareness among blind parents that technology often fails to work properly as it is supposed to when it should. As an example, in voice assistants and screen readers, the mechanism of these devices is that they read texts from digital book files with the aid of automated speech instead of the human voice, while the texts inside the books are usually detected and recognized by OCR functionality [55]. A problem with this mechanism is that in case the text is abnormally scanned, such as misspelled and missing words, the voice assistants and screen readers will not be able to detect the malfunction. It is possible that even the devices themselves are unable to detect the problems, so blind parents might not be able to detect any problems with the devices themselves. There is a problem where some words are mispronounced, as stated by P0,

P0: "This is the problem with the audio that you were talking about because you can't check the characters."

As a matter of fact, the concerns raised aren't merely due to some functional failures on the part of the devices, but even to the technology itself. When it is a situation that might be impossible to use the technology to work properly, P2 believes that Braille is another way that can be used.

P2: "You know Braille, unfortunately, is a dying thing. Because I can just text anyone to with the phone. I always tell people, though, if you learn braille to kind of keep using it, and I try to remind myself. Keep using it because it is helpful, and it's a good backup when you know your technology or whatever doesn't work, and it's just good for some things."

Requires Keeping Up with Latest Technology

We found that some blind parents (P0, P2) are unwilling to keep tracking the latest technology to read digital books. Even though new accessible functions and devices are developed to serve disabled people better, blind parents have a disproportionately high burden of learning about the accessibility of mainstream technologies, which are used by sighted people. P0 mentioned that a friend of hers, who is a tech teacher, is still having trouble with his daughter's Amazon Fire Tablet. She elaborated on the potential risks associated with purchasing these new devices at high prices, expressing concerns about their lack of familiarity with mainstream devices and the possibility of not being able to utilize them effectively,

P0: "It's so hard for parents. Parents want to get their kids tablets. Have a friend who is blind, his wife is partially sighted. He's a tech teacher. They got an Amazon Fire tablet, still trying to figure out how to work it."

One of the reasons for this problem is the unwillingness of blind parents to change their current reading habits. P2 expressed that she does not use digital books because she is already well-acquainted with a specific book platform she has used for a long time. This does not imply that she is unwilling to embrace new technology; rather, she prefers to maintain her established reading routine and does not wish to alter the way she has always read.

P2: "I'm always going to use the same thing with Bookshare. I've used that since the early 2000, so those ones will always be my first option because I always use them. They're so easy. They're so easy to use."

Their hesitation to adopt the latest technology is partly due to their perception that these devices haven't been updated much since they first tried using them. As parents who are

blind, it has been hard for them to get a firsthand experience of the advancements that have taken place in technology. They instead rely on hearsay from other blind parents and sighted individuals who mention using such devices, often highlighting the improved accessibility features of the device as the reason for their use. P0, for example, mentioned the absence of a text-to-speech function on Amazon Kindle. However, it is worth noting that Kindle has supported this functionality for several years.

P0: "I don't know about Kindle. They are accessible in some ways but not all ways. Though I heard a lot of sighted people using it, there aren't a lot of blind people who use it from who I know. Those are Amazon but they don't have VoiceOver."

Hard to Navigate Through Book Contents

The lack of accessibility in book navigation is one of the major reasons why blind parents do not read digital books to their children. For instance, P1 highlighted the lack of structure in the table of contents across all the digital books he encountered. Despite the fact that tables of contents are intended to serve as a navigational aid in various books, there are often inconsistencies in the way they are organized, making it difficult for P1 to locate them in a consistent location, such as on the first page of the main content of the book.

P1: "Like if the maps have them in a way where like useful like it's just reality, but if it was actually structured in a way where you can sort of get the idea of where things are located will be useful."

When discussing the main content of a book, P1 expressed a preference for the page that directly corresponds to the beginning of the main content, rather than the first page, such

as the title page. He mentioned that he does not want to navigate from the first page every time he opens the book again.

P1: “Honestly, I prefer the ones that dropped me read through the book and not landing at (the) first page.”

P1 also discussed the functionality of their primary reading device, Amazon Kindle. They mentioned that Kindle's navigation feature only allows them to navigate through book texts by single characters or words. This limitation has posed difficulties for P1, as it requires them to go back and read the text again using single characters and words, which is an unfriendly user experience for blind individuals.

P1: “It only will be manually navigated by individual characters or a word at a time. (If) having the ability to read sentence by sentence, would also make the reading like listening in that setting what it said back out easier because it's like instead of having to manually loop through a single line one word at a time. I can have it, just tell it to read one line.”

According to P1, it is challenging to differentiate between different levels of headers when reading digital books on a phone. Headers play a crucial role in aiding navigation for blind users [13]. However, P1 mentioned that headers on Android phones lack distinguishable differences, resulting in a diminished level of accessibility.

P1 (Android): “There's no differentiation of headers or even heading one heading two... I connect to that external keyboard you can get the header levels for the keyboard hooked up to that basically switches to up.”

Contrastly, another blind parent, P4, who uses an iPhone to listen to audiobooks, said that the iOS system provides a commendable level of accessibility. However, when comparing

digital books to audiobooks, P4 finds the former less user-friendly. While audiobooks allow users to navigate using a scrolling progress bar, digital books with screen readers lack this functionality.

P4 (audiobook, iPhone): "It is very accessible on my phone or iPad to navigate (digital books), perhaps a little less user-friendly, in regards to navigating compared to audio. I might want to like, Go back, and I want to listen to that quote again, or bookmark that I find a little less user-friendly to use digital books with my screen reader."

Chapter 5

Discussion, Conclusion, and Limitations

The vast majority of previous works have explored reading interaction and supportive technologies between sighted parents and sighted children [35, 41, 57, 80, 90, 97], or sighted parents and blind children [56, 78, 86], yet, there is still a lack of research focused on reading interactions between blind parents and sighted children [87]. Moreover, although we have the knowledge of different methods to co-read between blind parents and their sighted children from the previous study [87], we still lack knowledge of the role of digital books in their co-reading process and whether digital books are worth using when co-reading. This study highlights how digital children's books from commercial book vendors are inaccessible for blind parents and the factors that explain blind parents' preference for printed books over digital books when reading with their children.

To demonstrate the contribution of my findings, I compare and discuss my findings with other research in the following three sections: 1. Blind parents' experience shows that existing assistive reading technologies do not work in co-reading contexts; 2. Both digital

books and twin-vision books cannot provide an accessible reading experience for blind parents with children 3. Blind parents have concerns about using digital books in co-reading with children.

Target Population	Sighted Parent	Blind Parent
Sighted Child	[35, 41, 57, 80, 90, 97]	[87]
Blind Child	[56, 78, 86]	N/A

Table 5.1: Reference related to different target populations

5.1 The Need for Natural Interaction and Context

Most of the previous HCI works focused on supporting reading for people who are visually impaired by enhancing the interactivity of assistive technologies [21, 30, 62, 63, 65, 82]. Among assistive technologies, most of the research targeted the screen reader, as it is integrated with text-to-speech functionality, which can assist in providing auditory information. The enhancements made by previous research have proven to be valuable in enhancing the quality of reading for PWVI, whether it be for personal, professional, or leisure purposes.

However, my findings show that when co-reading with their children, blind parents encounter challenges that do not align with the same assistive technologies used for personal reading. For instance, all parents in my interview study indicated they seek a screen-free and headphones-free reading experience with their children in the bedroom, whereas most assistive technologies rely on displays and headphones [87]. My study found that using external assistive technologies such as screen readers will lead to a lack of interaction with children. Children can easily focus on manipulating the book elements like pictures, colors, and other manipulable elements [33]. However, digital books commonly do not have the tactility and visual elements that are capable of drawing the attention of children, as P0 and P2's experience shows. Even more, e-ink devices such as Amazon Kindle do not provide any

color except for black and white, which may contribute to the loss of children's attention. This is also why blind parents show less awareness on whether images are present or not in their personal digital books, but they hope there are accessible pictures to stimulate and educate their children.

Apart from visual issues, the synthesized voice produced by assistive technologies is also not suitable for co-reading. Previous studies have reported that blind parents find the mechanized voice of screen readers to be obtrusive and irritating. This leads them to opt for headphones to listen to the voice alone while repeating the words to their children. They emphasized the importance of children hearing their parents' own voices and interpretations [87]. Similarly, my study found that blind parents want to read books in their own voice to their children, without being read by the voice assistant or screen reader with machinery voice. As P4 said, reading to children on their own is definitely what parents need to do and want. Due to their blindness, they may feel a sense of responsibility to confront ableist assumptions about their parenting abilities. Parents might feel involved in their children's learning and development when they read in their own voice. These are the factors why most blind parents prefer digital books for themselves and twin vision books for co-reading.

5.2 The Need for Accessible Book Format

Previous research explored and contributed to making digital book format to be accessible [21, 30, 65]. Not surprisingly, there are numerous accessibility challenges with twin-vision books for blind parents. There may be opportunities to provide access to children's books via different, more appropriate interaction modalities (e.g. voice assistant, vibrotactile feedback, screenless wearables, etc.); however, in order to do so, we need a robust digital book format with adequate accessibility metadata for children's books. Unfortunately, my content analysis identified several issues that may lead to inaccessible co-reading experiences for both

blind parents and children.

I discovered that the official accessibility guideline checking application, known as Ace [1], is unable to detect all of the alt text tags within digital book files. This limitation stems from Ace's scanning process, which only detects the actual alt text tags embedded into the raw HTML file by the book provider. As indicated in my content analysis, out of an average of 39 images in the book, only 9 alt text tags were detected. This deficiency may lead to a situation where book providers assess the accessibility level of the book using the Ace accessibility evaluation tool but fail to comprehensively detect alt texts, resulting in an inaccurate measurement of accessibility. However, despite missing detection on alt texts in digital books is important to keep books accessible, a more significant concern is the absence of appropriate image descriptions that blind parents can understand in our sample. Even from a blind parent's interview, she had a twin-vision book with image descriptions in Braille from the first page of the book. As we are aware, twin-vision books are specifically designed to cater to both individuals with visual impairments and sighted individuals, offering content in written language and Braille. It is frustrating that none of our samples can provide useful image descriptions, only with “background image” embedded into alt text. This emphasizes the frustration and challenges by blind parents when seeking accessible reading materials to interact with their children.

While Ace Accessibility Checker is not a comprehensive tool that can provide evaluation for all accessibility features specified in official guidelines, the lack of image accessibility within my sample is still unacceptable. It is possible that book providers are not utilizing this tool before publishing digital books. However, I must acknowledge that this assumption is based on my limited sample of books from a single book vendor, as I did not further explore digital book publishing. This study emphasizes the necessity for accessibility evaluation tools to be made mandatory requirements in both accessibility guidelines and web content guidelines in order to provide a more inclusive reading experience since it is still not listed in accessibility

guidelines and the guideline is in its early stage of development.

Embedded texts in images also led to a new accessibility issue, particularly concerning text alignment failure. The digital book format lacks uniformity, with EPUB files, for example, typically comprising HTML files containing book texts, scanned images from printed books, and a navigation file as a table of contents. This format is generally considered a standard for EPUB file hierarchy, meeting the minimum accessibility guidelines for accessible digital books [7]. However, I observed instances where book contents and texts are scanned together with images, resulting in texts becoming an integral part of the images and unable to be separated from the book. Consequently, these texts within digital books lack customizability and adjustability for users. This poses a problem when blind parents wish to read the same book using different book reader applications and screen readers, as these applications often have distinct customization settings. Even when standard digital book files with texts separated from images are used, similar accessibility issues arise when utilizing different applications. I noted cases where the text is accessible to a screen reader but not visually accessible due to overlapping text alignment. The words are nearly incomprehensible, even for sighted people, if it is completely overlapping. Similarly, blind parents might not detect visual accessibility problems related to font and background color contrast until their family members or children, who can also read the book, inform them of the issues. This contrasts with twin-vision books, where blind parents can identify incorrect texts using Braille but may still encounter challenges in determining the importance of images.

Although this study does not focus on digital book publishing, it is crucial to discuss the page layout of the printed books when being scanned into digital format. Children's books, consisting mainly of images, require individual image descriptions for each image to ensure accessibility. However, some images in children's books are presented consecutively, with both sides of the page sharing the same contextual information. For example, children might see a monkey on the first page pointing to an apple on the second page, while there

are different fruits on the second fruits as well. Sighted children can easily understand the sequence of events depicted in these consecutive images. However, blind parents might face barriers that sighted parents do not have; even if appropriate image descriptions are provided for both pages, blind parents will receive different descriptions, such as “Monkey is pointing” and “different fruits.” This could lead to misinformation between blind parents and their children. Moreover, blind parents might have difficulties guiding their children accurately regarding what is happening in the book, potentially influencing the children's learning and development negatively. Based on these findings, it is suggested that image descriptions should be assigned to a set of contextual images rather than each image individually, especially when dealing with consecutive images in children's books.

5.3 Concerns as Blind Parents

Earlier research has focused largely on reading interaction between sighted parents and their sighted children [35, 41, 57, 80, 90, 97]. These studies consistently reveal that printed books are the preferred medium for fostering parent-child interactions, as they are commonly used during bedtime routines and family bonding moments [41]. Plain digital books, which contain only text without images, have been found to significantly reduce and limit interactions, such as conversations, between sighted parents and their children [80]. Similarly, in my interview study with blind parents, I observed that they also prefer using printed books for fostering intimacy and bonding with their children, similar to sighted parents. While I did not specifically evaluate how blind parents utilize plain digital books in this study, I did find that blind parents encounter challenges with digital books with a substantial number of images. These challenges included the lack of interactivity with assistive technologies, limitations of the digital format, and inadequate image descriptions. As a result, children often lose interest in book reading, and this might lead to reduced interaction between blind

parents and their sighted children.

Some research has also explored incorporating tactility into children's books to enhance their learning processes [56, 78, 86]. Researchers have observed that blind children benefit greatly from physically touching and feeling the actual objects described in tactile books, as they cannot rely on sight to understand the content before parents explain it to them. In our study, given that the children are sighted, they may still derive some benefits from tactile books; however, visual information remains the primary way for them to acquire knowledge during their learning process. Interestingly, blind parents mentioned similar reasons for valuing tactility and visual elements as educational tools for their sighted children. For example, as P2 said, using Braille books is not fair for her children because the children cannot see anything except for Braille. They also place significant importance on developing their children's early literacy through tangible elements, allowing them to teach with their own interpretations using tactile support. Sighted children would be primary readers instead of parents after gaining a level of literacy [87], and my findings suggest that providing accessible reading experiences in the early stages of children's development is crucial for facilitating the shift in roles between blind parents and their sighted children.

5.4 Limitations and Future Work

Though this study explored the accessibility state of digital children's books, the limitations of this study need to be acknowledged. Firstly, the sample size of books examined in this research is relatively small, comprising only 14 titles. Consequently, this sample may not fully represent the vast amount of commercial digital books available to blind parents. Moreover, the data collection was limited to digital book data from Google Play Books, which may not capture potential differences in accessibility across other online book vendors. Unfortunately, the accessibility checking tool used in this research environment could only analyze books

in the EPUB format, leaving out other formats like AZW digital book format from Amazon Kindle.

Furthermore, the recruitment process for participants presented communication challenges. Despite publishing the recruitment posts on online forums such as Facebook and Reddit, there were significant delays in receiving responses to email inquiries. Moreover, some individuals who initially expressed interest in participating chose not to respond to subsequent messages, leading to a limited recruitment of only five participants in total.

I hope future research can focus on expanding the topics from this study: First, conducting in-depth observational studies. Blind parents engaging in co-reading digital books with their children can provide invaluable insights. By closely observing these interactions in authentic scenarios, researchers can gain a deeper understanding of the accessibility challenges that arise during co-reading. Second, an examination of the publishing process. I found a lot of accessibility issues might happen before blind parents purchase the book. Investigating the publishing process of several online book vendors is essential to identifying how accessibility is hindered. Last, the prototype development incorporates design implications from prior studies on digital book accessibility. The prototype can include features such as augmentation of interactive elements for sighted children and more accessible functionalities for blind parents, which can support the co-reading process with digital books.

5.5 Conclusion

In this study, I first evaluated the accessibility of 14 digital children's books with content analysis. The content analysis includes three aspects of accessibility: book metadata accessibility, book format accessibility, and image accessibility. As a result, none of the digital children's books in our sample met official accessibility guidelines for digital books. Specifi-

cally, the sample books showed poor image accessibility, and there were no accessible images in the sample.

Afterward, I conducted qualitative interviews with 5 blind parents with sighted children to understand the challenges of authentic experiences when using digital books with their children for co-reading. I identified several factors that contributed to their decision not to use digital books, including 1) lack of accessibility features, 2) the difficulty in navigating the books, and 3) lack of physical interactivity. Most notably, blind parents do not desire to use digital books when reading with their children because, most often, they read before bedtime, and they want to avoid using screens. I used these findings from the content analysis and interview study to provide suggestions for including more natural interactions into assistive technology with accessible images to support an accessible co-reading experience for blind parents and their sighted children.

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Appendix A

Interview Protocol

Study Information

The purpose of this study is to understand how blind users read digital books and what accessibility issues exist when reading digital books.

Start Interview

Introduction (About interviewers)

Ask For Consent

Have you had a chance to read the study information sheet I emailed you?

This study aims to understand whether blind parents use digital books to read by themselves and/or with their children, the reason for using digital books or not, and opportunities for new technologies to make reading more accessible. We will record the interview for data analysis purpose. The interview will last for approximately 60 minutes. Do you have any questions?

Start Recording

Do you mind if I start recording now?

Ask to Introduce themselves

1. Basic information
2. Gender
3. Age
4. Cohabiting with any other adults
5. Braille usage

Interview Questions

[Use of digital books]

- Do you read digital books?

Yes – What is your preferred device (laptop/phone, screen reader) to read?

– What types of digital file formats do you read?

– What reader applications do you use?

– How do you choose which devices / file types / apps to read with?

No – What types of book formats do you read?

– Is there any specific reason for you to not use the digital book?

- Is there a typical place/platform to purchase/download books?

Yes – Why?

No – Go to next question

- What other platforms do you purchase/download digital books from? What are their differences?
- How accessible are digital books? What are the typical issues you encounter?

[Reading books with children]

- How many children do you have? What are their names and ages?
- Tell us about the kinds of books you read with your children?
 - Picture book or text book?
 - Can you share some titles of books you read with your child?
- Do you read digital books with your children?

Yes – What is your preferred device (laptop/phone, screen reader) to read?

- What types of digital file formats do you read?
- What reader applications do you use?
- How do you choose which devices / file types / apps to read with?

No – What types of book formats do you read?

- Why don't you read digital books with your children?

- How frequently do you read (digital) books with your children?
- For how many years have you been reading digital books with your child?
- What other platforms do you purchase/download digital children's books from? What are their differences?
- What difficulties do you encounter reading digital books with your children?

- What is the difference between reading (digital) books for yourself as opposed to digital books with your children?
 - Any usability / accessibility differences?
 - Do you do anything differently with your children? Why or why not?

[Opportunities for digital children's books]

- How important is it for you to know what's in the pictures in your child's books?
 - Why is it / isn't it important?
 - What strategies do you use to find out what's in the pictures?
- In your experience, do digital children's books have alt text?
 - Is that common or rare?
 - How good is the alt text?
- Are digital children's books generally accessible?
 - Are they easy to navigate? What is the issue that you encountered with [The way you navigate]
 - If the way you navigate the book does not work, what alternatives that you can navigate?
- What should digital books be like in the future? / What features do you hope will be added to make digital books better for reading with your children?

End of the Interview

- Is there anything else you would like to tell us about your experience reading digital books?

- Which email address is best to use for your Amazon gift card?
- Do you know any other blind parents of young children who might be interested to participate in our study?