Barclay College

Bible for the Deafblind: Tech-produced Graphics of Symbolic Universal Notation Are Feasible but Not Yet Accessible

A Capstone Research Paper

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Abstract

Those who are Deafblind are restricted in the way they have access to texts, notably the Bible. For them to access such texts, there are two preconditions: first, a suitable language; second, a practicable means to display texts in that language. Fortunately, the problem of a suitable language has already been resolved: Wycliffe Associates created the SUN (Symbolic Universal Notation) language to provide a Bible in a tactile, symbolic form for this population. The outstanding precondition is the problem investigated in this paper: namely, Wycliffe Associates' current method for printing the three-dimensional SUN language is time-consuming to produce and extraordinarily cumbersome to transport. The investigation sought out fresh solutions among existing assistive technologies based on tactile and refreshable capabilities, to determine if they were able to tech-produce the SUN language in a low-cost and light-weight format. Two studies were conducted. The first study used a qualitative design to survey technology companies who have developed assistive devices for the blind; this was to discover if they had tactile devices, and if those devices could feasibly tech-produce graphics of the SUN language. The second study used content analysis of the results of the first study, to investigate whether the tactile devices had refreshable graphics and could provide the Deafblind access to extensive SUN texts, notably, the Bible. Study 1 revealed that current technology does allow display of the SUN text. Study 2 revealed that said technology is not yet capable of providing it in an accessible cost-efficient way.

Introduction

It is the researcher's opinion that every person, regardless of disability, has a right to equal access of information. Those who are Deafblind are restricted in the way they can receive information and require unique solutions to provide them this access. God's holy words in the Bible are deemed one of the most essential documents to read. Wycliffe Associates created the

SUN (Symbolic Universal Notation) language to provide a Bible in a tactile, graphic form to meet this need for the Deaf and Deafblind that are illiterate ("SUN" 2020). It is the production of the SUN Bible in tactile form that turned out to be the difficult part of the equation.

The researcher has firsthand knowledge of the current format for the SUN Bible. It is printed using a three-dimensional printer called the Fusion 3. It prints two verses at a time using PLA 3D Filament. The process takes seven hours to print merely two verses. One complete Bible in this format would fill a tractor trailer. The extended length of time to produce it, and the excessive bulk of the three-dimensional format, make it infeasible for providing a Bible to the Deafblind worldwide.

The Bible in this entirely new language was intended to serve the Deafblind globally. Determining how many people would benefit is challenging to calculate. This is because Deafblindness is largely undefined, misunderstood, and concealed in many countries. This twice exceptional diagnosis, of being both deaf and blind, is considered a low-incidence disability and comprises an underserved population (Harrington and Pfohl 2006, 1). In 2008, the National Consortium on Deaf-Blindness estimated that there were 50,000 Deafblind in the United States (National Library Service for the Blind and Print Disabled Library of Congress 2019). Global calculations report 600,000 Deafblind worldwide (Burke 2012).

In searching the literature, the researcher could not locate any studies addressing the concern of Bible access for the Deafblind. Current Deafblind research is mostly centered around medical and emotional issues. Only a small sample of inclusion articles were discovered. According to the literature, research in the field of Deafblindness is emerging, but there is still much to be discovered in the areas of prevalence, literacy, and intervention (Nelson and Bruce 2019, 17-19; Hodges et al 2019, 22; Bruce, Ferrell, and Luckner 2016, 55). There also remains a gap in knowing how technology can help the blind access information (Middleton 2007, 7). Some researchers conclude that this chasm is "clear evidence of a lack of awareness of the need to develop accessible technology, and levels of knowledge in effective inclusive design techniques are disappointingly low" (Gregor, Sloan, and Newell 2005, 45).

It is the purpose of this research to discover if there is a way to tech-produce the SUN graphics to reduce the production time and immensity of the final product in an affordable way. This proposed concern would add to an underexplored area of Deafblind research. If the SUN Bible can be produced in a tactile, refreshable format, that is also affordable and compact, an entire population of people will have an accessible Bible.

Definitions of Terminology

Deafblind

Deafblindness is on a spectrum and has differing definitions, variations, and related terms. It is defined by US federal law, as "concomitant hearing and visual impairments, the combination of which causes such severe communication and other developmental and educational needs that they cannot be accommodated in special education programs solely for children with deafness or children with blindness" ("Deaf-blindness" 2020). The term Deafblind implies that a person has a dual-sensory impairment. These impairments impede an individual's ability to communicate, receive an education, live independently, and access information (Bruce, Ferrell, and Luckner 2016, 47; National Library Service for the Blind and Print Disabled Library of Congress" 2019). The United Kingdom includes development and education in their definition of Deafblindness that "relate to difficulties with communication, access to information, mobility and orientation" (Hodges et al 2019, 8). For the sake of this paper, the term Deafblind will be used and capitalized to distinguish it as a unique cultural group comprised of individuals that cannot see or hear.

SUN

SUN is an acronym for the language created by Wycliffe Associates. It stands for Symbolic Universal Notation. It was created to provide Scripture to the Deaf and Deafblind who do not know how to read (“SUN” 2020). It is a universal language, so those persons without access to braille can have equal access to the symbolic characters.

Summary

Wycliffe Associates created the SUN language with the global Deafblind population in mind. The current tactile format of SUN keeps it infeasible for providing Bible access to the very population it seeks to serve. This research sought to find a tech-produced solution to this problem by investigating the existence of current devices on the market that could feasibly produce tactile, refreshable graphics of the SUN Bible in a low-cost and portable format.

Study 1

Methods

Design

This was a qualitative design using descriptive, ex post facto research with alternative hypotheses employing survey research. It compared six qualities of current, tactile, graphic-producing technology in hopes of finding a feasible device to display the SUN Bible for the Deafblind who do not read braille. The independent variables are tactile graphics, refreshable screen, SUN font compatibility, data storage, weight, and cost.

Participants

Eleven technology companies were selected on the basis that they already had current assistive products known to service the blind. This purposive sample was representative of the main technology companies found at The Perkins School for the Blind's e-learning blog. The Perkins School is renowned for its services for the blind and Deafblind (Perkins 2020).

Companies that develop assistive products specifically for the blind were chosen over companies that develop mainstream products and then adapt them. Accessibility was a key factor in answering the research question, and it is important that accessibility is at the forefront of the product-development process. When it is considered "an afterthought rather than at the beginning of any design process…development tools and authoring tools do not tend to promote or encourage design of optimally accessible technology, and rarely if ever give any indication of whether or not the system which will be produced using these tools will have an adequate level of accessibility" (Gregor, Sloan, and Newell 2005, 11). Mainstream adaptive devices are initially designed assuming the user will be able to interact with the device with their eyes and ears. "Anyone with impaired hearing or vision may encounter significant accessibility barriers when using inappropriately designed technology" (Gregor, Sloan, and Newell 2005, 15). It is for these accessibility concerns that the researcher interviewed only the companies listed with Perkins, as they represented a sample of companies who have developed assistive devices.

The technology companies chosen were Harpo, APH Technologies, Humanware, HIMS, Freedom Scientific, VisioBraille, Handy Tech, Eurobraille, Optelect, and ORBIT Research. These are international companies with multiple devices designed for the blind. Though their devices are not specific to the Deafblind, if all variables were present, the research question, *is it currently feasible that tech-produced graphics of the SUN language are capable of providing*

Bible access to the Deafblind, would have been answered positively. The researcher anticipated a return rate between 80-90% with high motivation since the participants would likely be sales representatives from technology companies desiring to share product information with interested parties.

Setting

The Data were collected and recorded in a consistent manner over a three-month period (June – August 2021) in the researcher's home in the United States of America. The researcher used an internet search to locate pre-selected participants. Participants were invited by email or web form to complete the survey with the full disclosure about the SUN language and the need to find a tactile product for the Deafblind. The researcher's cellphone and email were used to administer the survey.

Materials

The researcher used a computer with internet capabilities to obtain the contact information for each participant through their respective websites. The Data Analysis Sheet in Appendix A contains a complete list of each company and their contact information.

The researcher emailed each company a letter of inquiry (Appendix B). When the company responded and agreed to be interviewed, a survey script (Appendix C) was used to interview each participant that responded.

Procedures

The three-month process began by accessing The Perkins School for the Blind's website for their most recent e-learning blog on tactile devices. The researcher recorded each technology company on the Data Analysis Chart (Appendix A).

The next step was to utilize Google's search engine to find each company's website and contact information and record their phone number and email. If a customer service number was given, it was also recorded (Appendix A).

When no email was provided, the researcher used the company's website platform to submit the letter of inquiry (Appendix B).

When an email was provided, the researcher sent the letter of inquiry to the company (Appendix B) and waited for a response.

When a company called the researcher in response to the inquiry, the researcher proceeded with the survey script (Appendix C) and recorded their answers on the Data Analysis Chart (Appendix A). When a company emailed a response back and agreed to be interviewed, the researcher emailed the survey script (Appendix C). The responses from the email surveys were recorded in their proper columns in the Data Analysis Chart.

When a company did not respond, the researcher would call the company's USA phone number, if provided on the website. When no USA phone number was provided, the researcher would locate a different email or web form to send another letter of inquiry.

Results

The survey provided the answer to the beginning of the research question, *is it currently feasible that tech-produced graphics of the SUN language are capable of providing Bible access to the Deafblind?* Study 1 revealed that it is currently feasible to tech-produce the graphics of the SUN language in a tactile device. It also revealed that the capability of the technology is indeed emerging but not currently on the market.

Summary of Current Technology from the Literature

The first step necessary was to investigate current technology available that utilizes tactile features since persons with Deafblindness rely heavily on their sense of touch. The touchscreen devices presently on the market have limitations that make it difficult for blind users to rely on this sense to navigate the screen (El-Glaly, Quek, Smith-Jackson, and Dhillon 2013, 245; Gustafson, Rabe, and Baudisch 2013, 890; Kane, Bigham, and Wobbrock 2009, 1). McGookin, Brewster, and Jiang's study revealed the problems with touchscreen accessibility and found touchscreen technologies lacked necessary tactile cues to distinguish the controls from the display space (2008, 1-2).

The literature revealed that some research has addressed the accessibility concerns of touch screen-based systems, but this involved additional hardware that is not consistently available or accessible (Kane, Bigham, and Wobbrock 2009, 2). One such hardware was an overlay created by Humanware that enables blind users access to the devices' functions but is only compatible with resistive screens (Johnsen 2010, 14). Additional hardware means more components, which can mean more technical complications (Fuglerud 2011, 7). Another solution includes audio feedback. This provides necessary interface information for the blind user but is not beneficial for a

Deafblind person (El-Glaly, Quek, Smith-Jackson, and Dhillon 2013, 245; Gustafson, Rabe, and Baudisch 2013, 890; Johnsen 2010, 12).

Vibrotactile and refreshable braille displays

There are two types of assistive technology that have been designed specifically for the Deafblind (Parker, McGinnity, and Bruce 2011, 9). First are vibrotactile devices, on which DeWitte reports, "the ability for touchscreen controls to move from two physical dimensions to three dimensions may soon be possible. Though solutions exist for enhanced tactile touchscreen interaction using vibrotactile devices, no definitive commercial solution yet exists for providing real, physical shape to the virtual buttons on a touchscreen display" (2008, iii). Secondly, refreshable braille displays make computer text accessible for the Deafblind (Johnsen 2010, 13). However, current assistive technologies, including vibrotactile devices or communicators with refreshable braille, are not capable of multimedia contents (Kim, Park, and Ryu 2019, 1). One study proposed a 2D multiarray braille display device that was able to display images on the braille device simulator, but it was not enough to express the details on the targeted 11x11. The researchers concluded that "further research is required to display photographs and pictures that contain several objects on the braille device using the limited number braille characters" (Kim, Park, and Ryu 2019, 21). Even when images can be displayed, relevant background information is not accessible (Kopecek and Oslejsek 2012, 106).

Future devices

Further possibilities may be on the horizon. DeWitte noted that, "a new interface solution may be possible by inverting the traditional touchscreen architecture and integrating emerging technologies such as organic light emitting diode (OLED) display and electrorheological fluid based tactile pins" (2008, iii). She cites a study by Klein et al (2005) that uses electrorheological fluids to move pins on a three-dimensional tactile surface (2008, 40). Pins would be raised and lowered relative to the surface, which could then be read with the fingers.

Summary of Current Devices from the Survey

The survey conducted confirmed the findings in the literature. Feasible assistive technologies exist with tactile features and refreshable graphics. However, responses from the participants were low. Out of the ten companies contacted, six responded and were interviewed. One interview covered two companies since the Product Manager who was interviewed represented both. One company was added after a recommendation from one of the participants.

Figure 1 shows the overall response of the companies contacted. Four did not respond. Three reported that they had no current, feasible product. Three answered that they had a feasible tactile, graphic device.

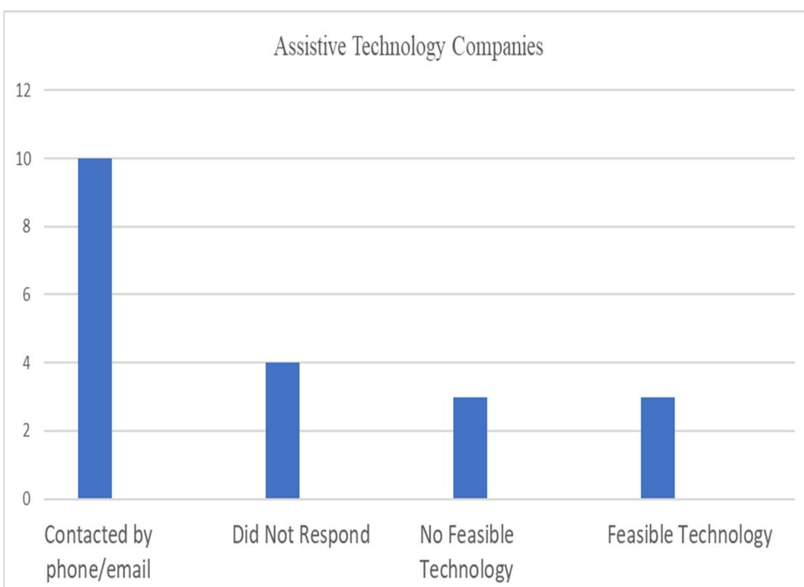

Figure 1. Bar Graph Data of Participants Contacted and Their Responses

Feasibility determination

Three of the companies surveyed had feasible products to answer the research concern. Feasibility was determined by the technologies' ability to produce tactile, refreshable graphics. The literature supports the importance of tactile methods to provide information since the nature of Deafblindness requires such a provision. The United Nations' Educational, Scientific and Cultural Organization acknowledges this in its preamble: "Recognizing the importance of accessibility to . . . information and communication, in enabling persons with disabilities to fully enjoy all human right and fundamental freedoms" (United Nations n.d.). The United Nations then includes display of text and tactile communication in its definition of terms (Watkins 2011, 22). Middleton's research found that Australia's government included tactile forms when it focused its efforts on providing information in accessible formats (Middleton 2007, 10).

There is evidence that tactile forms are effective for providing Deafblind individuals access to information (Bruce, Randall, and Birge 2008, 8; Buzzi et al 2013, 1; Hodges et al 2019, 22; Nelson and Bruce 2019, 16). Buzzi's et al investigation showed that blind users of touch-based mobile devices had effective interactions when using a tactile channel because "cortical brain areas normally reserved for vision may be activated by tactile stimuli" (2013, 1). In addition, Bruce, Randall, and Birge listed the sense of touch as one of the qualities needed for Deafblind children to learn (2008, 8). Tactile interaction provides visualization through the sense of touch that cannot be provided by the eyes. Middleton shared findings from Brewster and Pengelly that supported the importance of the blind to have "visualization through technology" to access information (Middleton 2007, 25).

Tactile interaction is vital for those with Deafblindess to access information, but this comes with technological challenges. Designers must consider "transition time, hardness, shape and height" while minimizing "dimensions of shape and height to provide tactile benefit" (DeWitt 2008, 37-38).

Adding refreshable graphics to the tactile experience was necessary to reduce the bulk of the current method of printing three-dimensional hard copies. However, adding refreshable graphics to technology adds more complexities. The reward is that large amounts of graphics can be displayed (Rao and O'Modhrain 2020, 1). The way it works is that "the device receive output from the screen readers and produce lines of Braille character with small pins that raise and lower as the user navigates a screen and encounters text" (Mulloy, Gevarter, Hopkins, Sutherland, and Ramdoss 2014, 130). Research on tactile graphics supports the use of this technology with students who are blind. According to the literature, "raised line graphics are associated with greater concept comprehension than relief-based graphics" (Mulloy, Gevarter, Hopkins, Sutherland, and Ramdoss 2014, 139).

Limitations of braille devices

Of the six companies interviewed, one had braille-only technology. Globally, braille is the accepted form of written language for the blind. However, only 133 of the 7,000 plus languages have such a code, creating a barrier to literacy ("World" 2020). In nations like the United States who have a code, less than ten percent of children with blindness, ages 4 to 21, are considered braille readers ("Braille" 2019). Even amongst those individuals that are blind but can hear, braille is not a system that is widely used ("Braille" 2019; "Braille Literacy Crisis" 2009, 1; Middleton 2007, 7). The National Federation of the Blind labeled this a "crisis" ("Braille Literacy Crisis" Blind 2009, 1). For the Deafblind, braille is even more difficult because "there are rules for the use of contracted braille which rely on understanding how a word sounds or is segmented. . . these rules may not be understood by someone who cannot hear the sounds" (Hodges et al 2019, 25).

Additionally, even if the Deafblind person learned a braille code, technology that displays it may not have the capabilities needed to completely answer the research concern. The universal nature of the SUN language removes the barrier for those Deafblind individuals who do not read braille or have access to a braille code in their language, making the need for customized font essential for answering the research concern.

Hard-copy graphics

One company responded that they had technology that could produce customized, tactile graphics but only in hard copy format.

Refreshable and customized graphics

One company had a device that had refreshable tactile graphics, the capability to display SUN font, and data storage available both on-board and via SD card.

Emerging Technology

Furthering technologies are emerging, and question ten yielded four similar responses pointing to an unnamed tactile product being developed by a joint venture between Humanware and APH that could potentially meet all the necessary criteria in the future. No additional information was available. One interviewee mentioned an additional device developed by Blitab Technology that seemed promising. However, requests for an interview were not answered.

The remainder of the research focused on the three feasible tactile, graphic devices named in question one to determine their accessibility features and were analyzed in Study 2.

Study 2

Methods

Design

This was a qualitative design using content analysis comparing three tactile, graphic-producing technology devices that emerged from Study 1. The technologies were analyzed for their capabilities to use refreshable graphics, display customized graphics of the SUN language, and store large data for Bible content. Their accessibility was analyzed for weight and cost.

Participants

This purposive sample was representative of the three tactile, graphic technologies that emerged from Study 1. These technologies included Harpo's PIAF, VisioBraille's Windows Tablet Display, and Orbit Research's Graphiti. This sample was chosen because they represent the only feasible technologies from Study 1 potentially capable of answering the research concern.

Setting

The Data were analyzed in the researcher's home in the United States of America.

Materials

The survey responses from the Data Analysis Chart in Study 1 (Appendix A) were compiled into Figure 2's table in the Results section.

Procedures

The researcher extracted the feasible technology information from Study 1 found on the Data Analysis Chart (Appendix A) to create a new condensed chart. Question one began the first row and listed each device's name at the top. Then the five qualities from questions two through six were added to the left column. The data collected from questions two through six were compiled and placed into their proper categories in the chart. The researcher analyzed each device for its capability, based on questions two through four, and its accessibility, based on questions five through six.

Results

Study 2 showed that the devices analyzed could not provide Bible access to the Deafblind. The emerging theme is that tech-produced graphics of the SUN language are currently available and capable but are not economically accessible.

Accessibility in the Literature

The last concern of this research involves accessibility factors. Though technology is increasing in capability, the literature reviewed revealed that those with visual impairments often do not benefit because of accessibility issues (Gregor, Sloan, and Newell 2005, 4; Kim, Park, and Ryu 2019, 1). The high cost of the devices is often listed as a factor (Chowdhury et al 2018, 1; Gregor, Sloan, and Newell 2005, 4; Middleton 2007, 7; Mulloy, Gevarter, Hopkins, Sutherland, and Ramdoss 2014, 131; Rantala et al 2008, 28). This should be a major concern considering that "80% of all people with a disability in the developing world live in what can be considered poor living conditions" (Watkins 2011, 16). If the technology that contains the SUN Bible is too costly, it remains out of reach to those who need it.

The other accessibility consideration is “poor portability” (Rantala et al 2008, 28). As previously mentioned, Wycliffe Associates’ current method of three-dimensional printing produces a very large Bible that is difficult to transport, hence the need for refreshable graphics. Since the goal is Bible access for the Deafblind globally, the solution must also be light weight, for ease of delivery and use.

Analysis from the Survey Data

The PIAF, Windows Tablet Display, and Graphiti were named as tactile, graphic devices by their respective technology companies. Study 2 analyzed each devices’ capability and accessibility to determine if they could provide a SUN Bible to the Deafblind. The Windows Tablet Display and Graphiti use refreshable graphics and have an SD port for storage options. Of those two, the Graphiti was the only one capable of displaying customized font. The three products discussed weigh between three to thirteen pounds. The PIAF was the heaviest product. It is a machine that requires specialized paper and costs $1,395. The Graphiti weighs 8.3 pounds and costs $14,995. The lightest product, the Windows Tablet Display, is a tablet that is solely Braille-based and costs $5,499. Figure 2 is a breakdown of each device by their specifications. The chart is organized from least to most expensive.

Device	PIAF Tactile Image Display	Windows Tablet Display	Graphiti
Refreshable Graphics	No	Yes	Yes
Customized Graphics	Yes	No	Yes
Hardware Data Storage	No	Yes	Yes
Weight	13 lbs.	3 lbs.	8.33 lbs.
Cost	$1395	$5499	$14995

Figure 2. Tactile, Graphic Devices Discussed in Interviews.

The PIAF (Picture in a Flash)

The first product analyzed was the PIAF Tactile Image Maker by Harpo (see Figure 3). It provided a paper alternative to refreshable graphics and did not need storage because it produced a hard copy. It could function with customized graphics because it heated up the Tangible Magic Paper to swell the symbols that had been printed on it. However, the cost of the printer, and specialized paper it required, kept it economically infeasible in providing Bible access in the SUN language to the Deafblind. In addition, the excessive bulk of a hard copy text of the SUN Bible in this format would near equal the current three-dimensional method currently used by Wycliffe Associates.

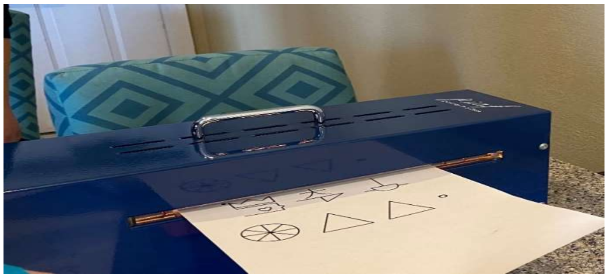

Figure 3. The PIAF Machine with Magic Paper
(photo taken by researcher)

The Windows Tablet Display

The second product analyzed was the Windows Tablet Display. It was the lightest device of the three and is braille based. Since it did not have the capability to display the SUN font, no other analysis was needed.

The Graphiti

The third product analyzed was the Graphiti (see Figure 4). Orbit Research developed the Graphiti that houses 2400 pins at varying lengths. These pins can display tactile graphics. Rao and O'Modhrain's study found the tactile, input-output capabilities were useful (2020, 3).

It had all the technological capabilities to produce the graphics of the SUN language as well as the storage capacity of the SUN Bible. In addition, it had been used by Deafblind individuals, and the research was published online. The weight of the product was reasonable for transporting. However, Rao and O'Modhrain found "the limited touch sensitivity and low mechanical resolution were a ubiquitous challenge. Touch based interactions of tactile representation demand accurate touch input and displays that have a distinct contrast when using varying heights and textures for representation" (2020, 3, 9). In addition, the cost made it infeasible for providing Bible access to the Deafblind who need it globally, as each Deafblind individual would need their own Graphiti.

Figure 4: Picture of Graphiti by Orbit Research
(photo taken by researcher)

Discussion

The main finding of this qualitative research design revealed the existence of current devices available capable of producing the SUN graphics. However, such devices are not feasible for providing Bible access for the Deafblind. This supports existing theories that cost effective assistive devices for the blind are lacking.

DeWitt's investigation found that, "assistive tactile devices have not developed at the same rate as other touch related market segments. One explanation is that auditory devices such as text to speech systems appear to be a major focus for commercial development. Another explanation is the lack of technological solutions for tactile devices" (2008, 45).

The second finding of this research study revealed that additional products are under development and may provide technology capable of producing SUN graphics in a lightweight and low-cost way in the future. In his interview, Mr. Jarek Urbanski, CEO of Harpo, wrote, "we have access to some technology that would allow that, but plans to use that for a two-dimensional refreshable graphics are vague and even if we do that, it will take several years, and resolution of the picture may appear not sufficient for your needs" (2021).

This means that exploration of non-tech solutions may be necessary to meet the need now.

Assumptions and Limitations

This study assumed that products for the blind would also meet the needs of the Deafblind so long as audio feedback or voice-over features were not necessary in the device's functionality.

The researcher is concerned about the external validity of the sample of participants. Are they representative of all the companies that produce tactile graphic technology? These participants were chosen because they were recommended by the nation's leading school for the blind. The researcher expected their knowledge base to cover the most comprehensive assistive products on the current market. This limited the scope of the research. Other technology companies could have been inadvertently excluded, and the limited sample may potentially have been biased. The last question of the interview attempted to compensate for this limitation by asking if the interviewee was aware of other tactile, graphic devices on the market. This revealed two additional devices. One device was created by a technology company not listed on the Perkins School for the Blind's e-blog.

The research was also limited to technology companies who specialize in assistive devices for the blind under the assumption that these companies would have the most innovative products to meet the literacy needs of the Deafblind. This excluded technology companies that develop mainstream devices for all users but also offer adaptive features for the blind.

The research did not seek to interview companies that produce tactile images using three-dimensional printing. In the researcher's experience, this method of tech-produced graphics has been time-consuming to produce. In addition, the SUN Bible, in its current three-dimensional form, is large in quantity, making it heavy and not feasible for wide-spread distribution. It is because of these time and size challenges that the research did not go beyond the scope of technology companies with devices capable of storing the SUN graphics. The interview method revealed the PIAF Image Maker as a tactile possibility, but this was not the researcher's main intent.

Future research

The world's population should have access to the Bible in a language they understand. Those with Deafblindness require unique solutions to meet this need. The SUN language was developed to provide a universal and intuitive way for the Deafblind population to read the Bible in a symbolic, tactile format. This format is challenging to distribute. Future research should be conducted to alter current appropriated and assistive devices into potential prototypes that could display and store the SUN graphics in a compact and affordable way. Perhaps it is possible for a single device to be adapted to serve those without sight or hearing.

Other solutions may be found through observation of different market segments outside the appropriated and assistive blind devices. There may be lightweight paper alternatives used in other industries that could replace the heavier three-dimensional hard copies presently available.

This would require a printer that produces tactile symbols but would eliminate the need for a device that holds the data.

Bible access for the Deafblind is an underrepresented research topic that deserves greater attention. On-going research is vital to find real-time solutions to meet this need. A low-incidence disability like Deafblindness should not equate to low priority.

Appendix

Appendix A

Data Analysis Chart

	Company #1	Company #2	Company #3	Company #4	Company #5	Company #6	Company #7	Company #8	Company #9	Company #10
Name of Company	Harpo	APH Technolgies	Humanware	Orbit Research	HIMS	Optelect	VisioBraille	Handy Tech/Help Tech	Eurobraille	Blitab Technology
Time/Day Contacted	28-Jun-21	sent web message on 7/8/21 and 8/12/21; send emal 8/12/21, called and left message 9/9.21	6/28/2021	6/28/2021	8/12/2021	6/28/2021	8/12/2021	emailed Handy Tech 6/28/21; emailed dreamvision 7/8/21; emailed sales 8/12/21	submitted web form 8/12/21, received response 8/30/21, I sent questions 8/30/21, I send follow-up 9/9/21	emailed info email 8/17/21 and emailed Kristina Tsvetanova 8/30/21
Company Information	jurbanski@harpo.com.pl	cs@aph.org, + 1 800 223 1839	andrew.flatres@humanware.com	1 904 202 2280	thomas@hims-inc.com 1 888 520 4467	Rpopovits@Vispero.com 1 727-803-8000, includes Enhanced Vision, Freedom Scientific, Optelect, and TPGi	USMKT products sold by Master Distributor, InsideVision igor.feinberg@insidevision-us.com			
Contact Person	Jaroslaw Urbanski, CEO	unable to contact	Andrew Flatres, product manager for braille and tactile products	Customer Care Team	Thomas Simpson	Rick Popovits, Vispero Sr. Product Manager	Igor Feinberg	unable to contact	Jean-Matial ROUX, sales manager, but never received answers to my questions	unable to contact
What is the name of your tactile, graphic device?	PIAF with Tactile Magic Paper			Graphiti	None	Not currently shipping any products supporing mulit-line braille display with tactile graphics	Widows Tablet Display			
Does this device use refreshable graphics? Can you describe the refreshable graphics function?	No		Not possible to include SUN in the current form of refreshale braille device	Yes, moving pins			Yes			
Can customized graphics be used with this device, such as symbolic font?	Yes			Yes			No, braille-based			
How much data can this device's hardware hold?	None			SD card and USB compatible. Device does not hold data.			64 gb on-board and 128 gb SD card			
How much does the device weigh?	5.9 kgs/13 lbs			3.78 kg/8.33 lbs			3 lbs			
How much does this device cost?	$1,395			$14, 995			$5,499			
Do you know if any deafblind person has used your device?	Yes			yes			Yes, Helen Keller Headquarters purchased product			
Is there any research that has been done on this product?	Yes, SUITCEYES Research and Innovation Project			yes			Yes, France Manufactor insdievision-us.com			
If yes, can you please share where I can find this information?	suitceyes.eu/publications			Published Online			testing result on website			
Is there another tactile, graphic device besides this one?	There are vague plans but it takes several years		Humanware and APH are on a joint adventrue to create a dynamic tactile display that will be able to display such tactile forms. Still in early days and cannot give any informations as to when it will available	No	Yes, Humanware and APH are developing a mulitline tactile product. Mr. Simpson encouraged me to focus on on embossed saying that refreshable technoogy is too far off.		Graphiti, Blitab, and Human Ware & APH developing something similar to the Graphiti			

Appendix B

Letter/email of Inquiry

To Whom It May Concern,

My name is Stacy Shawiak, and I am the program manager of SUN (symbolic universal notation), a project created by Wycliffe Associates. It was designed with the Deafblind in mind. Using tactile symbol cards, we have been able to teach Deafblind individuals how to read, both in the US and overseas. I am seeking technology that can produce the SUN symbols in a tactile format.

Would you be willing to answer a few questions for me related to your tactile products? This would greatly help me locate the best device for the thousands of Deafblind globally.

If you are willing, please reply to this email or contact me at +1 386 281 7672 with a convenient time for us to talk. Thank you in advance for your time and consideration. Your products are making a difference to a very marginalized population.

Sincerely,
Stacy Shawiak
SUN Program Manager
Wycliffe ASSOCIATES ACCELERATING BIBLE TRANSLATION

Appendix C

Survey Script

Hello, my name is Stacy Shawiak. Thank you for your willingness to help me find tactile, graphic devices that can help the Deafblind around the world. I appreciate the important role (insert company's name) plays in helping the blind access information. I have ten questions related to your products.

1. What is the name of your tactile, graphic device?
2. Does this device use refreshable graphics? Can you describe the refreshable graphics function?
3. Can customized graphics be used with this device, such as symbolic font?
4. How much data can this device's hardware hold?
5. Does this device have external data storage options, such as a SIM card reader?
6. How much does the device weigh?
7. How much does this device cost?
8. Do you know if any deafblind person has used your device?
9. Is there any research that has been done on this product?

If yes, can you please share where I can find this information?

10. Is there another tactile, graphic device besides this one?

(If yes, survey was repeated, and data recorded in a new field.)

(At the end of the call/email)

Thank you for your time. I really appreciate your willingness to help me. I will be contacting other companies to explore their products as well. Would you like me to share my findings with you?

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