Information Accessibility in the Form of Braille

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***Abstract*—Braille is often proposed by the uninformed as the optimal solution to providing an alternative to visual information to the visually impaired. The purpose of this article is to highlight the complexity of the braille user population and discuss the importance of understanding the use of braille as a solution for equal access of information. As part of the National Institute of Biomedical Imaging and Bioengineering (NIBIB) Rapid Acceleration of Diagnostics (RADx) Tech program and its goal to make home tests accessible to people with disabilities, a series of interviews with industry experts was conducted to better understand braille technologies and the braille user space. Published literature findings provided additional context and support to these interviews. It was found that expert consensus and data from published literature vary. The braille user population is complex and lacks consistent characterization. Visually printed media should not be solely relied on to communicate information. In conclusion, braille is one solution for improving access to information. Understanding the unique needs of braille users and how they engage with information in a world that is heavily reliant on visual content, is a critical step in developing and implementing non-visual alternatives that will collectively address information access.**

***Index Terms*—Accessibility, blind, braille, instructions, visual impairment.**

Introduction

Braille is a tactile writing system that converts letters, symbols, and typography to a system of raised dots [1]. Invented in 1821 by Louis Braille, the system is now accepted as a form of written communication for those with no vision due to the absence of reliance on the eyes and adoption of the use of touch [2]. Braille allows for users to be aware of various aspects of writing such as punctuation and paragraphing that auditory feedback alone can't articulate [2]. In many cases, this can be key to full understanding of content. Notably, there is a growing population of those with concurrent vision and hearing loss for which braille may be the only viable communication method [3].

The International Classification of Diseases 11 (2018) defines visual impairment (VI) according to visual acuity scores [4]. However, it is commonly believed that a true definition of visual impairment must also take into account *quality* of vision which is the result of a multitude of factors. Therefore, visual impairment is the functional description of a population composed of both those who are blind with no light perception and those with low vision who cannot have vision corrected with conventional methods [5]. Interestingly, a scoping review of literature found that eleven different terminologies were used to describe the deafblind population [6]. Ultimately, decision-makers create vision status definitions for different eligibility purposes (e.g., medical, tax, benefits). With the inconsistency in definition of VI comes added complexity in characterizing the population.

The United Nations' Convention of the Rights of Persons with Disabilities recognizes persons with disabilities' right to equal access of information and calls for assistive support [7]. Information exchange is a vital part of life and contributes to one's independence [8]. It should never be assumed that persons with disabilities will have mediators for assistance. When looking to provide information in an accessible fashion for all end users regardless of disability, commercial entities must consider cost for production and dissemination, which can create economic challenges for commercial adoption [9].

The National Institute of Biomedical Imaging and Bioengineering's Rapid Acceleration of Diagnostics (RADx) Tech program is supporting research to improve the efficacy of in vitro diagnostic (IVD) tests for detection of the virus SARS-CoV-2 [10]. The program placed significant emphasis on development and commercialization of at-home over-the-counter (OTC) tests that could be more accessible to people with disabilities, including individuals with low or no vision. In the process of this work, a series of interviews were conducted with 18 different experts and groups to better understand braille technologies and the braille user space. This consisted of industry experts, subject matter experts, manufacturing entities, software technology groups, and national organizations. Discussion was driven by the need to develop commercially viable solutions for providing traditionally visual information, in particular instructional content, in a manner effective for non-visual comprehension and use, for which braille is often proposed by the uninformed as an optimal

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solution. The purpose of this editorial is to articulate these findings with additional context and support from published literature.

I. Braille User Population

Published literature and experts alike maintain that statistics on the population of blind individuals and braille users are not well established. Studies lack the extensive first source research typically available for other common market groups, likely due to the comparatively small size of the population. The U.S. Census Bureau 2021 American Community Survey identified 7456432 civilians with vision difficulty [11]. This would account for 2.28 percent of the civilian American population (total population 326912, 547) [11]. However, other national surveys report widely varying numbers. Rein et al evaluated five other national surveys establishing VI prevalence rates and concluded that national surveys report widely varying numbers and that additional research is needed to accurately characterize the population [12]. Numbers vary between sources and data sets due to sampling bias, disability definitions used over time, and population sampled.

With regards to the number of those who read braille, there is limited data. Though sources agree that not all people with VI can read braille, the reported rates for braille literacy among the VI population range widely. The braille literacy rate most commonly cited in literature and by our interviewed experts is 10% of blind people. A systematic review of the literature in 2022 found that this statistic arose in the 1970s and is therefore now outdated and invalid [13]. The Adult Rehabilitation and Employment Survey (ARES) of 2011 surveyed 1056 individuals (702 blind, 354 visually impaired), one of the largest studies of this population to date and found that 58.05% of participants read braille [14]. According to interviewed experts, braille popularity varies between those with different levels and timing of vision loss. For example, a person who has never had functional vision may prefer braille versus a person who has previously had functional vision who may dislike braille. In addition, there are individuals who may prefer braille due to print reading challenges (e.g., eye strain, reading disability) that may not be captured by these studies. This leads industry experts to believe that the braille user population is severely underestimated, and there is a consensus that the braille user population is a significant portion of the print disabled community. Together, the lack of studies sampling large numbers of the visually impaired population and the confounding bias from the inconsistent definition of visually impaired inhibit an updated, well-established braille literacy rate.

One sometimes-overlooked segment of the VI community is the aging population. Many countries are experiencing an increased life expectancy due to advances in healthcare, shifting the burden of illness towards disabilities [15]. With an increased life expectancy and growing aging population comes the growth of the visually impaired population. Those who become visually impaired late in life adopt braille less frequently than those with lifelong or early onset VI. Reading braille requires both dexterity and cognition, capabilities known to decline with aging [3].

Braille literacy has a substantial impact on employment and income, and braille solutions must be considered in the context of cost to the end user. Assistive technologies such as screen readers with audio outputs compete with braille and significantly impact the number of braille users. The Global Burden of Diseases, Injuries and Risk Factors Study estimated that 90% of VI individuals reside in low-income settings [18]. Many studies have considered the relationship between braille literacy and employment rate with numbers varying between 65%–85%, and interviewed experts quote a 95% employment rate of braille users [19], [20], [21]. Harris et al found that "disabled individuals are more likely than non-disabled persons to live in poverty" [22].

Despite its long history and proven benefits to populations, braille literacy is decreasing today and has been declared a crisis [16], [17]. Disabled persons are the world's largest minority [22], and while the US braille user population may be relatively small at several million individuals, it is nonetheless a significant group that deserves equal access to visually available information to support independent living.

II. Braille Mediums and Cost

A. Printed Braille

Braille is an inherently physical medium and is produced primarily through braille printers embossing specialized braille paper or microcapsule paper capable of retaining the raised dots of braille. Text must first be transcribed to braille, which has a fixed minimum character size roughly comparable to 28pt font size. Braille pages are 11.5 $\times$ 11 inches or 11 $\times$ 8.5 inches and bound with plastic comb or spiral binding to form a booklet, and one traditional print page of text typically transcribes to three braille pages. However, particularly dense, information-packed documents could easily transcribe into significantly longer braille documents, particularly if they include complex content such as graphs, charts, or non-decorative images.

The production of embossed braille is significantly more involved and expensive than traditional printing across the entire process. A braille embosser requires content to be input via a braille ready file (.brf) in which each page of source text must be transcribed to braille by a certified transcriber, proofread, and checked for quality. Embossed braille is significantly more delicate than ink printing, wherein improper handling or embossing can render characters illegible. Verification of correct embossing is also more difficult than checking print where a visual scan of the document can easily determine any errors whereas braille must be felt line by line to confirm all characters are legible. Because of this, the production process is more demanding with more steps for quality production and distribution to ensure legible final documents.

Commercial prices for embossing reflect the effort involved to produce braille. At this time, print runs of 100 copies or more ranging from 25 to 45 cents per braille page depending on the vendor, and single copy production can easily cost upwards of one dollar per page. Transcription alone, while a one-time cost per document, is also roughly $6 to $8 at minimum per page of 12pt font source text based on quotes from two commercial

braille embossing businesses, though transcription of visual content (images, graphs and charts) may increase costs if alternative text is provided. The turnaround time for commercial production and shipping of transcribed documents is generally at least a few days even for single copy printing. Braille also requires a thick stock paper used specifically for braille embossing, which is more expensive than traditional copy/printing paper, adding to the material cost of braille production.

While personal braille embossers are available, these devices carry high cost for the consumer with prices for a small volume of devices ranging from roughly $1800 at the low end up to $5000. Different manufacturers also use unique formatting codes, meaning that the same .brf document may print differently on different embossers, posing potential challenges for distribution of text or .brf content for printing at home.

B. Braille Technologies

As an alternative to paper-printed braille, many braille users rely on refreshable braille devices. These are electronic devices capable of converting digital information to a physical braille format in a refreshable display system [23]. Refreshable braille devices electronically transcribe text from a computer screen or other digital input to braille characters through a series of cells on the device which raise and lower pins [24]. Two subcategories exist: braille displays and braille notetakers. A braille display generally does not have standalone connectivity to the internet or significant word processing power but instead functions in conjunction with screen reader software for computer, tablet, and smartphone use, or braille content may be uploaded directly to the device for reading. A braille notetaker is a standalone device which can directly connect to the internet and run onboard applications, similar to a computer, and does not make use of any visual display. With either of these types of devices, users can scan through digital content and interact with digital systems without the need for audio.

While braille devices provide significant benefit to the user, they are expensive with prices for a typical 32 or 40-cell device ranging from $3500 to $15000 in the US [24]. The cell count (i.e., the number of braille symbols that can be displayed on the device at once) is a major factor in cost, and larger 80 cell displays cost roughly $9000. Many researchers and manufacturers are exploring alternate, lower cost braille cell mechanisms, but costs remain high. Though lower cell count devices may be cheaper, interviewed experts suggested that utility of smaller devices is limited. One expert suggested a size of 20 braille cells as a minimum requirement for efficient day-to-day use. This size would balance both utility and cost. Interviewed experts identified braille devices as generally having a 5-year life cycle, plus or minus 2 years depending on the fidelity of the individual product, similar to the depreciation schedules for other electronic devices.

III. Access to Braille

Historically, the high cost of braille devices has severely limited access to them outside of educational programs. However, VI users in the workforce are generally able to obtain a device through federal programs, from which employers can request funds to purchase a device for the individual's work use. Additionally, there has been an increase in government and university investment into improving access to the visually impaired [25]. The National Library Service for the Blind and Print Disabled (NLS) recently launched a program providing free braille displays to all NLS patrons [26]. The device can be used like any typical braille display and load .brf files, but it can also connect to the internet for access to certain library sources for braille reading materials. NLS projected that this program would increase access to braille devices, however some industry experts believe that the installed base of braille devices would not increase dramatically because most US individuals who want a device are able to obtain them already.

Based on discussions with industry leaders, the installed base of braille devices is not well understood, with experts suggesting a range of numbers based on their own sales and estimates of the market. One CEO suggested less than 50000 units in the US while another national account manager estimated up to 2 million. An expert from a VI support organization suggested somewhere in the middle, around 400000 units, which was reached by estimating the number of fully blind individuals with the 10% rule and then considering how many of those are on fixed income. The clearest count of installed base comes from federally funded devices purchased by US school systems, which is 5000–8000 units. Regardless, the movement towards decreasing the cost of devices and the increasing trend in technology advancements in the US suggest that the population of braille device users is expected to grow significantly. The compounded annual growth rate of the global digital braille displays market is estimated at 20.5% up until 2027 [24].

IV. Information Accessibility

While braille may seem like a simple solution on the surface, production and distribution of braille documents for consumer markets pose many challenges for commercial implementation as the end-to-end process is fraught with financial and operational challenges. In many cases, these challenges are so significant that they prevent entities from pursuing braille in any form at all, leaving an underserved population.

Considering the use case of a medical device sold OTC, instructions need to be available at the point of purchase or in a timeframe comparable to the availability of standard instructions. With a high cost and large physical embodiment, printing braille for all customers, or just those who need braille instructions, is not sustainable, and an alternative is to instead provide content in a readily accessible digital format. Interviewed experts suggested formats including a responsive web page, an accessible .pdf document, or .brf document. An accessible webpage would serve the most users, capturing users from both the sighted population and the print disabled with screen readers paired with braille devices or with auditory output. A .pdf document removes the need for an active internet connection and may be easier to develop. A .brf document addresses braille device users that don't use computers or the internet as well as those that use embossers. However, in terms of usability, the .brf

option does not provide any significant benefit for braille device users over an appropriately designed webpage or .pdf.

Standards for formatting digital content for accessibility follow the Web Content Accessibility Guidelines (WCAG) published by the World Wide Web Consortium's Web Accessibility Initiative, and include features such as tagging focus order and alternative text descriptions for images, charts, and other graphical information [27]. Adherence to these guidelines ensures that digital content is accessible to users with screen readers and refreshable braille devices. Given the complexity of requirements, experts recommended that commercial entities work with digital accessibility experts for development or remediation of digital content.

Beyond creation of instructions for braille delivery, users need to be made aware of where to find instructions that are useful to them. This is critical and may be challenging with traditional advertising and product labeling considering the comparatively low volume of non-visual marketing.

V. Recommendations

The purpose of this editorial is to inform the IVD manufacturing community about the need to improve access to information for those with visual impairments and to overview the challenges and recommendations related to doing so. This is not a technical review of the Braille language.

The visually impaired population is not well defined or understood in large part because definitions of blindness and low vision vary. This ambiguity can be attributed to the need for assessment of disabilities from a bio-psycho-social perspective and for understanding functionality, including one's medical, physical, and environmental situation [8]. This complicates the assessment of the braille user population. It is further complicated by the fact that braille use is not based on identification with one specific disability but rather may be affected by a multitude of factors such as personal preference, economic barriers, or concurrent disabilities. The shortage of research around this population also contributes to disagreement across sources on population numbers. There is an evident need for larger population research to properly characterize the braille user community.

Refreshable braille devices enable access for braille users to the digital world, and while devices are expensive, cost-reducing advances in technology and federal programs to fund or distribute free devices to users in need are likely to expand user adoption. This is further driven by an increasingly technology dependent and savvy society. The traditional solution of printed braille documents mailed to users will likely phase out considering its high cost, and as technology proficiency grows, an increasing number of users are likely to adopt refreshable braille devices. Many solutions to the prohibitive cost of braille technologies and challenges of access to them have been proposed, such as screen readers and audio output, and many groups are engaged in research around these topics, but no clear gold standard has been identified. However, developing a better, more holistic and robust understanding of the end user and population will help professionals to better design accessible solutions [6].

The format recommendations described in this editorial generally extend to other areas where complex information must be presented clearly to naïve users who may be unable to access visual content. However, providing digital content in the form of braille is not a stand-alone solution and may not be ideal for all users since braille is not used by everyone in the VI population. Alternative methods of delivery exist such as various methods of audio, video with audio description, and more. The growth of these methods of delivery largely affects the growth of the braille market given that they may carry a lower cost to adoption by both producer and user, but they have their own drawbacks [24].

This editorial addressed the narrow scope of the braille user and visually impaired populations. For content to be truly accessible, it must be accessible to *all* end users regardless of disability. There are innumerable considerations when developing accessible digital content for all populations, and while published guidance exists, more research must be done to fully understand the challenges, pitfalls, and best practices associated with universally accessible design.

In conclusion, the definition of visual impairment is ambiguous and literature is inconsistent. The use of braille does not align with a strict disability identification: Not all people who have no or low vision use braille, and there are braille users outside of the VI population. Involving end users is paramount in human-factors based design, and with the braille user population not being well defined, this creates a potential for gaps when creating solutions accessible to all. Physically printed media (including braille print) should not be solely relied on to communicate information. Braille should be considered to improve access to information, and braille content can be communicated in both print form and electronically through refreshable braille displays. Cost and access to these methods are important points to consider for commercial entities and in order to create a complete plan for addressing accessibility, additional approaches must be considered. Understanding the unique needs of braille users and the visually impaired community in general, and how they engage with information in a world that is heavily reliant on visual content, is a critical step in developing and implementing effective solutions for these individuals alongside the sighted community.

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