"What Would I Want to Make? Probably Everything": Practices and Speculations of Blind and Low Vision Tactile Graphics Creators

Gina Clepper
University of Washington
Seattle, Washington, USA
gclepper@uw.edu

Emma J. McDonnell
University of Washington
Seattle, Washington, USA
ejm249@uw.edu

Leah Findlater
University of Washington
Seattle, Washington, USA
leahkf@uw.edu

Nadya Peek
University of Washington
Seattle, Washington, USA
nadya@uw.edu

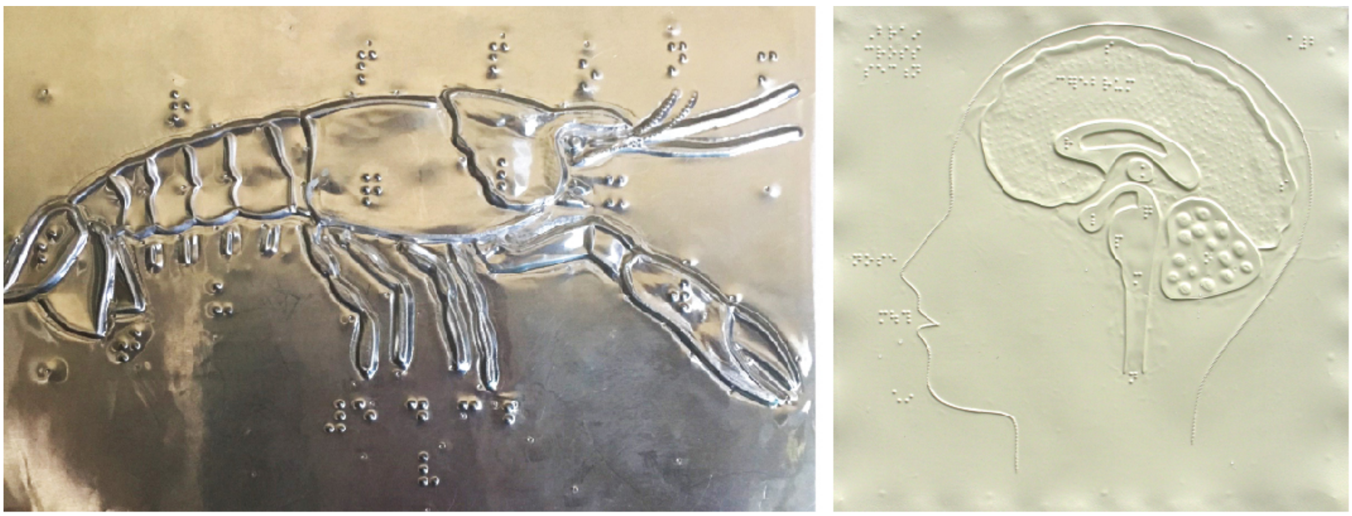

Figure 1: Two examples of tactile graphics made by the Princeton Braillists. Left: an aluminum original embossed tactile graphic of a lobster with different body parts labeled in braille. Right: a reproduction of a tactile graphic made through thermoforming over the original. Images from the National Braille Press [29].

Abstract

Tactile graphics communicate images and spatial information to blind and low vision (BLV) audiences via touch. However, designing and producing tactile graphics is laborious and often inaccessible to BLV people themselves. We interviewed 14 BLV adults with experience both using and creating tactile graphics to understand their current and desired practices. We found that tactile graphics are intensely valued by many, but that access to and fluency with tactile graphics are compounding challenges. To produce tactile graphics, BLV makers constantly navigate tradeoffs between accessible, low-fidelity craft materials and less accessible, high-fidelity equipment. Going forward, we argue that tactile graphics design and production should be made widely accessible and that tactile graphics themselves should be designed to be expressive and ubiquitous. Drawing from these design goals, we propose specific future tools with features for inclusive designing, sharing, and (re)production of tactile graphics.

CCS Concepts

• **Human-centered computing** → Empirical studies in accessibility; *Human computer interaction (HCI)*; **Accessibility**.

Keywords

Tactile Graphics, Blind, Low vision

This work is licensed under a Creative Commons Attribution 4.0 International License.
CHI '25, Yokohama, Japan
© 2025 Copyright held by the owner/author(s).
ACM ISBN 979-8-4007-1394-1/25/04
https://doi.org/10.1145/3706598.3714173

ACM Reference Format:
Gina Clepper, Emma J. McDonnell, Leah Findlater, and Nadya Peek. 2025. "What Would I Want to Make? Probably Everything": Practices and Speculations of Blind and Low Vision Tactile Graphics Creators. In *CHI Conference on Human Factors in Computing Systems (CHI '25), April 26–May*

01, 2025, Yokohama, Japan. ACM, New York, NY, USA, 16 pages. https://doi.org/10.1145/3706598.3714173

1 Introduction

As a volunteer with Recording for the Blind in 1965, Nancy Amick pioneered many of the techniques that are now central to the field of *tactile graphics* [29]. Amick, along with braille transcriber Ruth Bogia, led the volunteer "Princeton Braillists," embossing sheets of aluminum into raised, braille-labeled maps, books on human anatomy, and other scientific diagrams that could be understood by touch (Figure 1). Their collection was widely considered to be state of the art and continues to be distributed today after their passing. Yet, their story also reveals that the state of the art for tactile graphics *production* is often manual, bespoke work done by experts—and that the existence of high quality tactile graphics is uncertain when those experts are no longer at work.

Tactile graphics are made in a multitude of ways, including embossing, with crafting techniques, and by using swell paper [14]. Many of these methods require expensive equipment and expertise. To address these barriers to access, researchers in HCI and fabrication have taken up questions of how to make tactile graphics more widely available and intelligible. Recent years have seen novel methods for creating tactile maps [17], children's books [24], tactile circuits [10], and methods for rendering 3D shapes in 2D without relying on an understanding of perspective or parallax [31]. New methods for producing tactile graphics increasingly use new technologies such as 3D printing [16] or augmenting prints with QR codes [42]. However, recently, blind researchers have emphasized that these methods are almost never accessible to blind and low vision (BLV) people, limiting BLV people's agency and ability to design and (re)produce tactile graphics [3, 34, 36, 37]. This framing neglects that blind and low vision people are adept designers and makers, skilled at navigating inaccessible worlds [15, 43]. In this paper, we seek to understand the current practices of BLV tactile graphics creators and the challenges and opportunities for HCI systems research in this domain. We were guided by the following research questions:

- RQ1: How are blind and low vision tactile graphics users currently creating tactile graphics?
- RQ2: How and for what contexts do BLV people want to be able to create tactile graphics?
- RQ3: What discrepancies exist between tactile graphic production methods that are currently accessible to BLV people and the projected needs of BLV people?

To answer these questions we recruited 14 BLV participants who have engaged in tactile graphics design and creation processes. Participants joined us for a semi-structured interview focused on their use of tactile graphics, early and current experiences creating tactile graphics, and desires for future tactile graphic creation tools. We found that BLV tactile graphics creators encounter constant practical challenges, but navigate them creatively, often turning to craft materials over less-available and less-accessible specialized materials. Yet, while our participants demonstrated significant skill in navigating both inaccessible visual materials and inaccessible tactile creation tools, these workflows remain time-consuming and laborious. Moreover, we find that a variety of factors influence whether BLV people choose to engage with tactile graphics creation at all, such as whether they consider tactile skills to be useful and learnable and whether creators have supportive collaborators. Finally, the BLV creators in our study identified three strong priorities for future making tools: increasing the ease, prevalence, and collaborative nature of tactile graphics creation.

In summary, we contribute: (1) characterization of tactile graphics creation processes by BLV people and accessibility challenges therein, (2) design goals of ubiquity and expressivity of tactile graphics and accessibility of tactile graphics production for increased inclusion of BLV people in tactile graphics creation, and (3) speculative sketches of future systems that enact those design goals, enabling BLV people to design, fabricate, and share tactile graphics.

2 Related Work

The design and production of tactile media for blind and low vision audiences has been the focus of much research. Here, we summarize three relevant strains of work: the development of novel methods of tactile graphics creation, identification of challenges surrounding tactile graphics creation, and characterizations of existing practices of blind and low vision designers, artists, and crafters.

2.1 Methods of tactile graphics design and production

Tactile graphics encompass a broad array of touchable images, but certain types of tactile graphics are especially prevalent. These common types include: graphics made by producing debossed lines with a pen or stylus on paper or foil over a rubber board or other resilient surface; collaging with tactilely diverse materials such as paper and wax-coated yarn; embossing images out of dots made with a stylus, tracing wheel, or machine embosser; drawing or printing on microcapsule paper that swells selectively when heated; and thermoforming to mass-produce bas relief images from a single master [13]. Such hands-on techniques for making tactile graphics have remained prevalent among practitioners such as teachers and transcribers, [33], and these techniques are codified in existing tactile graphics design standards and guidelines [30].

Newer fabrication technologies have also been explored for tactile graphics creation. The adoption of desktop CNC cutting machines by crafters, for example, has yielded efforts to create affordable paper tactile graphics [21, 32, 48]. Computing advances have also enabled exploration of automatic generation of tactile graphics from 2D images [20, 25] and 3D models [31] as well as digital and authoring drawing tools for blind and low vision drawers [6].

Recent research has also led to significant progress in the development of pin-based refreshable tactile displays (RTDs), though such devices remain financially out of reach for the vast majority of potential users [35]. Force feedback displays and touchscreen-based interfaces [9] have also been used to render tactile graphical information [18] and support nonvisual design processes [43]. In their systematic review of recent literature on touch-based graphics, however, Butler et al. [9] found that tactile graphics remain the "gold standard" for communicating spatial or pictorial information nonvisually, against which these new developments are compared. For the time being, tactile graphics and the challenges surrounding their production remain relevant.

Moreover, little work has focused on whether these methods of tactile graphics design and production are accessible to BLV creators, and, if not, how to improve accessibility. BLV individuals are much more likely to serve as evaluators of than as participants in design or prototyping phases of the development of touch-based graphical access technologies [9]. In this study, we expand knowledge of the factors contributing to these divides between research and practice, presumed access and actual access, through direct interviews with BLV tactile graphics creators.

2.2 Challenges of tactile graphics creation

Prior work has highlighted many considerations specific to contemporary tactile media production. For example, in Stangl et al. [44], the authors utilize field recordings from participants at a Tactile Arts and Graphics Symposia, about half of whom were BLV, to identify problems of practice, such as prohibitive costs of tactile graphics production equipment and disagreement about codification of tactile design standards. Stangl et al. [44] argue that while many researchers have developed nonvisual creative tools and evaluated them in lab settings, "the space of inclusive media consumption and production in practice is largely unexplored." In this study, we aim to add to Stangl et al.'s work on in-the-wild tactile graphics production experiences, complementing their workshop observations with one-on-one interviews with exclusively blind and low vision participants.

The state of tactile graphics creation poses significant barriers to blind and low vision tactile graphic users—tactile graphics are limitedly available, production processes are largely inaccessible to BLV people, and the quality of tactile graphics is often subpar. In this paper, we report on our interviews with tactile graphic users to set directions for a future of accessible and available tactile graphics production.

2.3 Practices of blind and low vision designers, artists, and crafters

There exists a relatively long history of research seeking to characterize the tactile drawing practices of blind and low vision (BLV) artists. For example, Luebs et al.'s recent work on expert crafting practices of BLV creators has taken a similar methodological approach to the one we propose here, using semi-structured interviews with crafters [27]. Our study aims to build on such research by providing a contemporary account of practices of BLV creators of tactile graphics specifically.

Prior work by Race et al. [35] and De Greef et al. [12] has explored the topic of BLV-led tactile graphic creation through autoethnography and with a focus on mixed-ability team dynamics. Race et al. present an autoethnographic account of Blind-led design of tactile graphics, highlighting the role of trust in partnerships with sighted collaborators, as well as the bottleneck effects that occur [35]. De Greef et al. [12] similarly offer an experiential account of nonvisual design workflows for a team of blind and sighted colleagues who seek to share responsibility for access interdependently [12]. They describe group norms such as making the labor of access evident. Autoethnographic case studies from expert teams of blind and sighted collaborators and researchers have made significant contributions articulating the scale and scope of the problem created by inaccessible tactile graphics production processes. We build on this work with participants representing a wide range of expertise and experiences and translate those findings into recommendations for future fabrication practices.

3 Methods

To understand the experiences and needs of blind and low vision tactile graphic creators, we conducted semi-structured interviews with 14 BLV participants who both use and make tactile graphics. This study protocol was approved by the University of Washington's Institutional Review Board.

3.1 Participants

We interviewed 14 participants who were at least 18 years old, self-identified as blind or low vision, and reported having experience both using and creating tactile graphics. We also piloted the study protocol with one additional participant who met the inclusion criteria; the pilot was used to refine our protocol, and the pilot participant's data was not included in our findings. Participants were compensated \$30–\$40 in the form of an Amazon gift card or check. [1]

We recruited participants through multiple channels: the National Federation of the Blind (NFB) Tactile Art and Tactile Graphics Specialist Group (TAGS) email list, the Lighthouse for the Blind, NSITE (an employment services organization for candidates who are BLV and/or veterans), the Inclusive Design Lab's research participant pool, and professional contacts in the field of tactile graphics production. Recruitment materials directed participants to a screening survey in Google Forms, from which 14 eligible participants were selected. These participants were chosen to maximize diversity of tactile graphics creation methods, levels of experience, and recency of experience represented in the study (e.g. including both active tactile graphics professionals and people who last made tactile graphics when they were students.)

Participants included seven women and seven men, with an average age of 42 (ranging from 25 to 75 years). Table 1 summarizes participants' self-described vision levels and their relationships to making tactile graphics. Participants represented a wide range of experiences with vision loss, with nine describing themselves as totally blind, completely blind, or having no usable vision (with at least four being blind from birth and at least three having some vision earlier in life); four describing themselves as legally blind, low vision, or having a *"tiny"* amount of vision; and one describing themselves as blind without additional description. Almost all (12/14) were both screen reader and braille display users, while the remaining two used a screen reader only or zoom/magnification only, respectively, to access their computing devices. One legally blind participant also used zoom/magnification in addition to a screen reader and braille display. Two participants also used an Optacon (OPtical to TActile CONverter) to read mail and other non-braille print materials.

[1] After recruiting and interviewing the first three participants, compensation was increased from \$30 for a 60-minute-long interview to \$40 for an 80-minute-long interview, in order to aid recruitment and allow sufficient time for the interview questions.

Table 1: Summary of participants' vision levels and relationships to making tactile graphics.

ID	Vision level	Relationship to making tactile graphics
P1	*"Totally blind [...] from birth"*	As a writer, P1 worked with a tactile artist who *"did the illustrations and I wrote the text [...] We went back and forth on a lot of it."* As a parent, P1 and her child *"would draw things together."*
P2	*"Some residual vision – non-usable"* – with onset *"in my 30s"*	*"I use [Wikki Stix] to teach the [Hebrew alphabet] to blind and sighted individuals for the purpose of teaching Biblical Hebrew and Hebrew Braille."*
P3	*"Totally blind from birth with light perception"*	As a tactile design consultant, *"I have used tactile drawing tools from time to time and am currently helping to develop [a tactile graphic] authoring tool."*
P4	*"Blind since birth [....] I do not have any usable vision"*	As a braillist, P4 uses the software TactileView *"to graph equations, shapes and other things, plus I use its extensive online catalog of graphics."*
P5	*"Blind with a tiny amount of vision"*	*"I've used the raised-line drawing board."*
P6	*"Blind with no light perception [...] since fourth grade"* – before, *"I had just a teeny bit of sight but nothing really usable"*	*"The last time I had to make a tactile graphic I believe I was in high school,"* e.g. plotting points with pins in math class.
P7	*"Legally blind"*	*"I do a lot of image processing, graphic design [...] I'm trying to incorporate tactile graphics into my repertoire."* P7 is *"in the process of having some of my illustration[s] converted to tactile"* via the library.
P8	*"Totally blind [...] I can see light, and that's pretty much it."* – *"I did have some vision when I was younger, but not [...] full vision"*	As an elementary school teacher, *"I use and create tactile graphics daily to teach my students who are also blind or have low vision."*
P9	*"Blind"*	*"I used it for math in my school,"* e.g. using *"sticky threads."*
P10	*"Totally blind"*	*"As a TVI over 30 years ago, I created tactile graphics with the aid of an assistant."*
P11	*"Completely blind"*	*"I assisted making a [tactile] graphic of the map of where I was going to college."*
P12	*"Legally blind"*	*"I sometimes prefer to create my own graphics,"* e.g. drawing a diagram of the fielders' positions in beep baseball.
P13	*"Very low vision [...] since early childhood"* – *"I have a small amount of visual sensation in one eye."*	As a student studying environmental science/geography, P13 created maps with GIS software, including *"trying to add some [...] tactile components to these map printouts."*
P14	*"Totally blind [...] from birth"*	P14 *"collaborated on designing a game to help students understand the characteristics of galaxies."*

3.2 Interview Protocol

The semi-structured interview protocol took 60 to 80 minutes per participant and was led by the first author over Zoom. The interview focused first on participants' background with tactile graphics, asking about their definition of tactile graphics and how and when they've encountered tactile graphics. Next, we asked participants about their experiences creating tactile graphics, focusing on their most memorable and frequent practices of creating. At the end of the interview, we asked participants about their desires for future tactile graphic creation and consumption workflows. The full list of interview questions is available in the supplementary materials. While some participants shared photographs of tactile graphics they created, our use of remote interviewing did not allow us to touch examples of the artifacts we were discussing.

3.3 Data Analysis

This data was analyzed using reflexive thematic analysis, led by the first author and reviewed by collaborators [7]. Our analysis was inductive, semantic, and realist. The first author conducted all interviews, transcribed them with the help of Otter.ai, and checked transcripts for accuracy. Throughout data collection and analysis, the team met frequently and discussed interesting features and patterns in the data. The first author maintained an evolving list of these patterns, along with exemplary data extracts, and met regularly with the second author who reviewed and validated or challenged these as potential codes. After collecting and reviewing the complete data set of transcripts and memos, the first author developed an initial codebook, grouping related patterns in the data; for example, stories about building tactile skills in case of further vision loss and stories about impermanence of services were organized under a singular code: "Should I invest?" in skills for tactile graphics. The first author applied this codebook to the first transcript, and the second author reviewed the coded transcript. After discussing any complications in applying the codes, they updated the codebook. The first author then coded six total transcripts, finalizing the codebook (available in the supplementary materials). At this stage, the first author mapped codes to broader themes; for example, the codes "Should I invest?" in skills and "Considering interpretability" of tactile graphics were used to synthesize the broader theme, "Conceptualization of tactile skills." After discussing these broader themes, the team determined they appropriately summarized the data. The first author sorted the remaining data according to these themes, also maintaining a code for data that challenged or complicated these themes. Finally, the second author reviewed the coding of the final transcript, assessing both how data was coded and verifying that the smaller set of themes well-encompassed data from that transcript. The broad themes constitute the subsections seen in Section 4.

3.4 Positionality

Thematic analysis emphasizes that all research is subjective and shaped by authors' positionality. The authors on this paper are all sighted, and the first author has worked as a tactile graphics professional.

4 Findings

In this section, we describe what factors influence tactile graphics engagement, how participants navigated practical challenges while making tactile graphics, and how they imagined better tools and systems.

4.1 How different factors influence engagement with tactile graphics

Participants pointed to a number of factors to explain when and why they used and created tactile graphics. Many described early experiences at home and school that encouraged their overall tactile engagement and comprehension. Beyond their early experiences, however, interviewees varied significantly in their continued engagement with tactile graphics. We found that people continued to use and make tactile graphics when doing so enabled meaningful experiences that they felt were worth the investment.

4.1.1 Experiences with the wider world of tactility. The blind and low vision tactile graphics makers we interviewed situated tactile graphics on a continuum with other forms of touchable media. When asked about their personal histories with tactile graphics, many participants began not with stories of images but with stories about touching taxidermy specimens (P1) or animals sculpted from Play-Doh (P4). Similarly, participants moved fluidly between discussing tactile graphics and touch experiences with art, suggesting *"it's kind of a fine line between art and information"* (P14). Stangl et al. [44] adopt a similarly flexible definition of tactile graphics, recognizing that the distinction from art depends on intent and context.

P3 credited these varied touch experiences with promoting her comprehension of tactile graphics: *"thankfully, [...] the adults in my life would just, like, let me touch a lot of stuff,"* allowing her to more easily *"translate"* the flattened representations of objects in graphics, something she now does often as a tactile design consultant. This matches findings from Phutane et al. [33] that real objects and 3D models can serve as "stepping stones" to understanding tactile graphics.

4.1.2 Individual and institutional support. Participants frequently described family and teachers as key figures supporting their early use and creation of tactile graphics. P1 recalled what it was like to be raised *"in a family where those things were valued"*:

> *"If my mom found time, God knows how she did it, she would take a print coloring book, and she would go around the perimeter of a picture with a pin and make little pinpricks so I could color within the lines. And I remember some picture of baby chicks that she did that for me. And I always wanted her to make all my coloring books accessible—which, she just didn't have the time to do it. But when she did, I just loved it, loved it, loved it, to the point that I still remember it."* (P1)

Later, as a parent herself, P1 described finding herself in the reverse role of coloring book creator for her daughter. For some BLV makers, home was or is a central location for ad hoc tactile media making.

Outside the home, almost all participants named school as a critical setting—and sometimes the only setting—of their tactile graphics use and creation. As participants who work in education explained, *"it's basically mandated by law that students [are] supposed to have free and appropriate accommodations"* (P4). The effect of such requirements is that BLV people often have formative experiences with tactile graphics at school, not only as users but also as makers. School is where one might learn to read embossed organic chemistry diagrams (P12), build plots using boards and pins to complete math assignments (P6), or make a collage for an art class (P8). It is a setting where students *"not only learn how to read [tactile graphics], they get some idea of how they are produced"* (P10).

Schools are also important as nexuses for individuals who support engagement with tactile graphics. P8, a teacher, described teaching as her opportunity to *"share the wealth"* by providing students with images *"as much as humanly possible."* Participants drew similar connections between influential exposure to graphics at school and gratitude for the labor of individuals like incarcerated transcribers (P3) or volunteers (P1) who made those graphics:

> *"They were women who set up card tables in their living rooms, or whatever, and sat down at night with their braille writer and copied the print books, so that blind kids would have copies of what the book the classroom was using. And books were, you know, they were always late, and they didn't have the volume that I needed and whatever. But when I think about the heroic efforts of these volunteers, who sat down and copied page by page, equation by equation, these textbooks, I mean, what an act of love."* (P1)

That the books were *"always late"* speaks to the complication of relying on individual educators and institutions for access to tactile graphics resources. P8 explained how those resources vary; as a teacher at a school for the blind, she has straightforward access to federal quota funding for educational materials, saying *"if I ask for something to make tactile graphics, I'll get it pretty quickly,"* an option itinerant teachers might not have. Other participants recalled being unable to keep graphics so that they could be reused (P9), or reported stories of peers dropping classes due to textbook transcription latency (P12). Many participants described the brunt of their making in relation to school, suggesting a drop in access to tactile graphics creation outside of the world of education. When resources and services are tied to particular individuals or institutions, *"something exists for a limited period of time, and you better get it while it's around"* (P1).

Finally, participants articulated a cyclical relationship between tactile graphics creation and education. For some participants, access to graphics enabled deeper understanding of certain subjects that would otherwise have been *"just a bunch of words and dates"* (P2); like P1, for whom geometry *"made sense to me the way algebra never made any sense to me"* because the textbook contained diagrams. Absent those opportunities, P13 argued that young BLV people can enter *"a catch-22"*, in which lack of education on certain subjects means that *"they're not really able to form a deep concept or interest in some of these underlying problems"* of those subjects, which in turn impacts the accessibility of those subjects. In such a cycle, lack of tactile materials *"forc[es] people into [...] less graphic careers"* (P12). Fewer BLV people working in certain fields means fewer people pushing for access to domain-specific graphics or tools of graphics creation.

4.1.3 Conceptualization of tactile skills. To explain their level of continued engagement with tactile graphics, interviewees often explained their perspectives on the usefulness of tactile skills, or "graphicacy." Graphicacy, analogous to literacy, describes the ability to understand and create graphics [45, 47]. P8 and P10, both teachers of the blind, argue tactile graphicacy is a skill worth building. *"Students need to learn to access and review tactile graphics"* (P10), especially if they anticipate needing to comprehend standardized formats of graphics, like those presented on state exams. Tactile graphicacy involves learning *"to approach the graphic"* and *"to glean information"* (P10) from it—to both navigate an image by touch and interpret its meaning. It involves parsing the conventions of two-dimensional visualizations, like perspective and scale, *"concepts that other kids just kind of picked up visually, like, from just walking around in the grocery store, you know, driving and looking out the window in the car"* (P8). This echoes Gardner [14]: *"Sighted children have to learn about parallax, representation of 3D objects by 2D projections, and use of spatial position in such things as maps and graphs. Blind children seldom have access to comparable tactile pictures."*

While learning braille might involve the use of formal approaches like the Mangold Program to learn strategies for tracking and navigating text (P10), many participants recalled their tactile literacy education as being less formal. At best, it was *"easy"* (P3) or *"intuitive"* (P5); at worst, as P14 joked, the strategy was *"have fun, good luck!"* Learning to navigate a tactile graphic is a crucial skill because of the *"part to whole"* (P8) nature of understanding tactile media; while a visual image can be glimpsed in its entirety, providing a near instant overview of its content, perceiving an image by touch involves first interacting with its details, then mentally assembling them to understand the whole image [14].

Participants described various pressures encouraging or discouraging them from sharpening these tactile graphicacy skills. As P4 observed of his students, the possibility of additional vision loss in the future motivates some people to build tactile graphics reading skills. Others described misunderstandings about tactile skills: *"parents don't realize that, like, blind children enjoy, like, coloring or drawing or making these sorts of things. And so like getting to be the first person to introduce them to, it is really cool"* (P8). These valuations of the utility of tactile graphics-related skills influenced participants willingness to use and make graphics. P1 and P5 were both skilled users of the Optacon (OPtical to TActile CONverter), a piece of technology used to render print and graphics vibrotactilely, which has not been manufactured for decades. Their regular, passionate use of a now-discontinued product that requires much practice to master is a radical example of investment in tactile skills.

4.1.4 Meaningfulness of experiences enabled by tactile graphics. People *"don't seek out graphics just for the sake of graphics"* (P5). Participants described engaging with tactile graphics when doing so enabled important professional, social, or personal experiences.

For some blind and low vision people, using and making tactile graphics is intertwined with professional opportunities. When P9 was in school, *"it was not allowed for blind people to go to the science track, only the literature track. But I did go to the science track. Like, I was the first. And so [. . .] the blind institute, kind of, like, cooperated, and so they produced [. . .] materials for me."* For P9, having accessible materials, including tactile graphics, was integral to having just access to education. Similarly, making effective tactile graphics was not part of P10's daily life *"outside of the context of being a teacher"* but was critical for that role: *"I was very concerned about being the best teacher that I could be, and that meant I really could not fail in this department."* Conversely, P5 wondered if using and making tactile graphics might be more important to her *"if I were a scientist [. . .] or mathematician."* As a piano player and educator who uses braille music and learns by ear, P5 engaged with tactile graphics *"not often, not anymore."*

Some participants sought out tactile graphics because it was important to them to participate in the world of images. For P1, it *"was just such a natural thing to do"* to go *"back and forth"* coloring or solving math problems with her daughter. P14 described herself as being innately *"just so curious"*: *"I was the person who wanted the braille world tactile atlas for my eighth birthday."* Tactile graphics

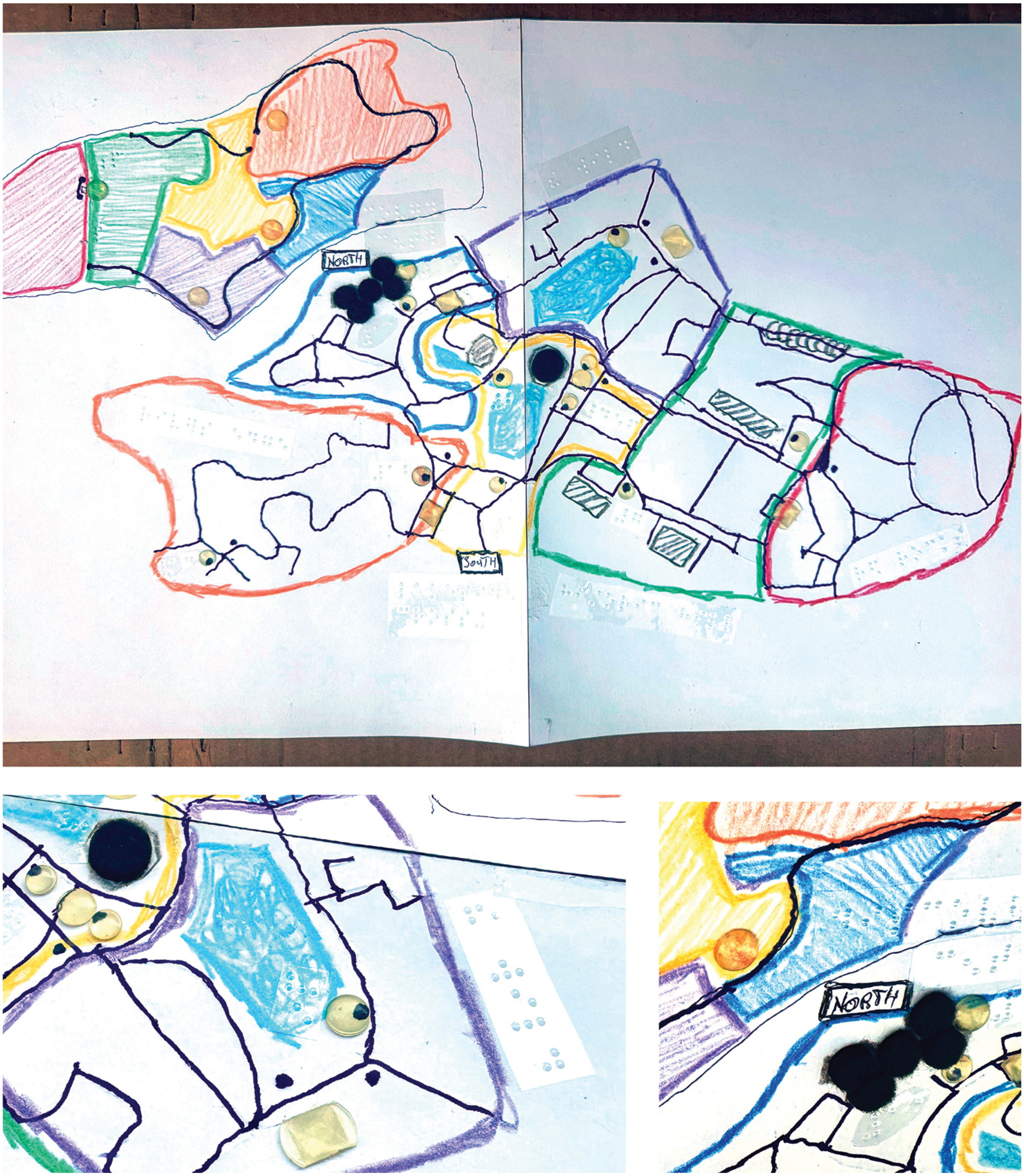

Figure 2: Low tech approaches to making tactile graphics often involve creative use of at-hand craft materials and household objects. Shown here is a tactile map of a zoo made by P12. The map is annotated with braille labels, curvy walking paths drawn with raised lines, and bump dots denoting large buildings, railroad stations, and concession stands. A smaller version of the map in the corner depicts the railroad route only. Details of the map are shown on the lower left and right, zooming in on some of the tactile elements.

could address that curiosity; to use them was *"to look at the thing, just like anyone else would"* (P3). Conversely, the feeling you were missing out on images could elicit *"grief and rage"* (P1): *"if your world is only as large as what you can explore, you're missing out [on] a lot"* (P2).

For some participants, making tactile graphics firsthand was a way to address those emotions. P1 *"was always so frustrated that braille books didn't have any pictures in them. [...] There was this wealth of pictures that I was not being allowed to get. And so I would try to make pictures to go into the books that I got."* To P1, tactile drawing could be not only *"fun"* but *"empowering," "like the world is trying to deny this to me, but I'm going to do it anyway."* Similarly, braillist P4 described feeling *"very confident and proud"* embossing a graph or a holiday card *"fully independently."* Imagining tactile graphics making as a more casual undertaking *"on par with the sighted world"* was especially appealing: *"there's nothing wrong with doing what everybody else does"* (P4).

4.2 How BLV people make tactile graphics while navigating practical challenges

Participants shared their typical tactile graphics creation processes, ranging from low- or no-tech drawing and crafting methods, to use of specialized or repurposed fabrication equipment. In doing so, they provided insight into how blind and low vision makers navigate practical challenges, make trade-offs, and consider factors of tactile perception.

4.2.1 Low tech approaches to making tactile graphics. Almost all participants recounted using analog tools and affordable, accessible materials to make tactile graphics *"on the fly"* (P8). These methods included drawing over rubber or foam boards with a stylus or pen to produce raised line images on sheets of paper or plastic (P1), or using a serrated tracing wheel to draw dotted lines (P10). Participants also created collage-style graphics using craft materials. P10 painted a vivid picture of the eclectic, *"free for all"* (P10) supply list of a tactile collage maker:

> *"So you would have buttons, you would have yarn, Wikki Stix, puff paint, lots of glue. You could have a hot glue gun [...] You could use uncooked pasta to do some stuff. You could use rice, [...] sandpaper of various grits, [...] small plastic items from a dollar store that you could actually glue onto there. I've seen people use items that are used to decorate cakes, that are made out of plastic for certain things, raid a Monopoly game for a hat."* (P10)

Other participants expanded that list to include crayons, clay, plaster, pipe cleaners, popsicle sticks, cardboard, foil—*"anything that would stick"* (P10).

Participants found a variety of uses for making handmade graphics, from sketching ideas (P3) to producing soft, flexible felt maps (P8). P2, a Hebrew teacher, shaped Wikki Stix (pliable wax-covered yarn) into glyphs and painted them onto canvas with primer to make her collage more durable. Using collage techniques to annotate existing graphics was common: *"adding braille, adding textures, adding more defined lines, adding little items like a button or a dot"* (P10). P12 shared an annotated zoo map he created by hand (shown in Figure 2) using adhesive bump dots, braille labels, and scored lines. As P5 put it, *"we just knew how to modify everything"* to enhance its tactility.

4.2.2 High tech approaches to making tactile graphics. Whereas low and no tech graphics making experiences were common, experience with specialized or repurposed technologies for tactile graphics making varied. Only some participants had access to such tools. These included educators like P10, who recalled having a thermoform machine to replicate collaged graphics at his school, and P8, who described using a braille embosser and braille labels to teach students the parts of a plant. P4, a braillist, routinely designed charts and prepared images for embossing using TactileView, a screen-reader accessible tactile drawing software. P4 and P10 had used tactile image libraries that allow users to search for, download, emboss, and modify graphics. Design consultant P3 sketched designs using a tactile drawing board that, once finalized, a tactile graphic producer reproduced using a flatbed UV printer.

Some participants used digital tools not designed for tactile graphics to augment their workflows. P8 described how she might start from a visual graphic and use *"Be My Eyes for the blind, or something like that, and have the AI describe it for me [...and] ask about any additional information I need to know about the image."* She would use that information to create her own graphic, or search online for a similar image from a coloring book, *"because they don't have all the color and detail to them, [and] they're usually pretty simple,"* making them easy to reproduce legibly on swell paper. Likewise, P7, who is legally blind and uses residual vision to take photos, described how he would *"use Photoshop to just convert them to outline only"* when fabricating tactile versions of his photos with a swell machine.

4.2.3 Navigating practical challenges by making tradeoffs. Participants described making trade-offs between these low and high tech approaches as they navigated considerations like time, cost, nonvisual usability, and collaboration.

Specialized equipment could offer accuracy and reproducibility, but the associated costs of machines and materials often limited their use and access. P7 described the commercially popular swell machine that he accessed through the library to produce the graphics in Figure 3. The *"little machine, like a heat lamp, to swell up the paper"* cost around $1000, and on top of that, *"the swell touch papers, I want to say, like each sheet cost around $1 or something—imagine, for a pack of 100, like $150 for a pack" (P7).* A dollar per graphic adds up: faced with similar concerns about the expense of braille paper, P4 imagined *"a day where I had [an] unlimited supply of paper [...] and an unlimited supply of, like, my software and an embosser that works all the time. Because if I had that, I would be testing out graphics like heck" (P4).* Such costs disincentivize iteration, especially given that *"the only way I can test the graph and find out if I was successful enough in rendering, is through embossing"* (P4). Cutting edge tools are prohibitively expensive: P14 noted *"the Monarch* [a refreshable pin-based tactile display] *is great, but it's $17,000. I don't have that kind of money laying around. And if you're not a student, you can't get quota funds... you just can't get it"* (P14).

Participants could only develop graphics with tools they had access too. For many high tech tools, *" individuals don't really have them" (P12)* —these are often a shared resource at a school or library.

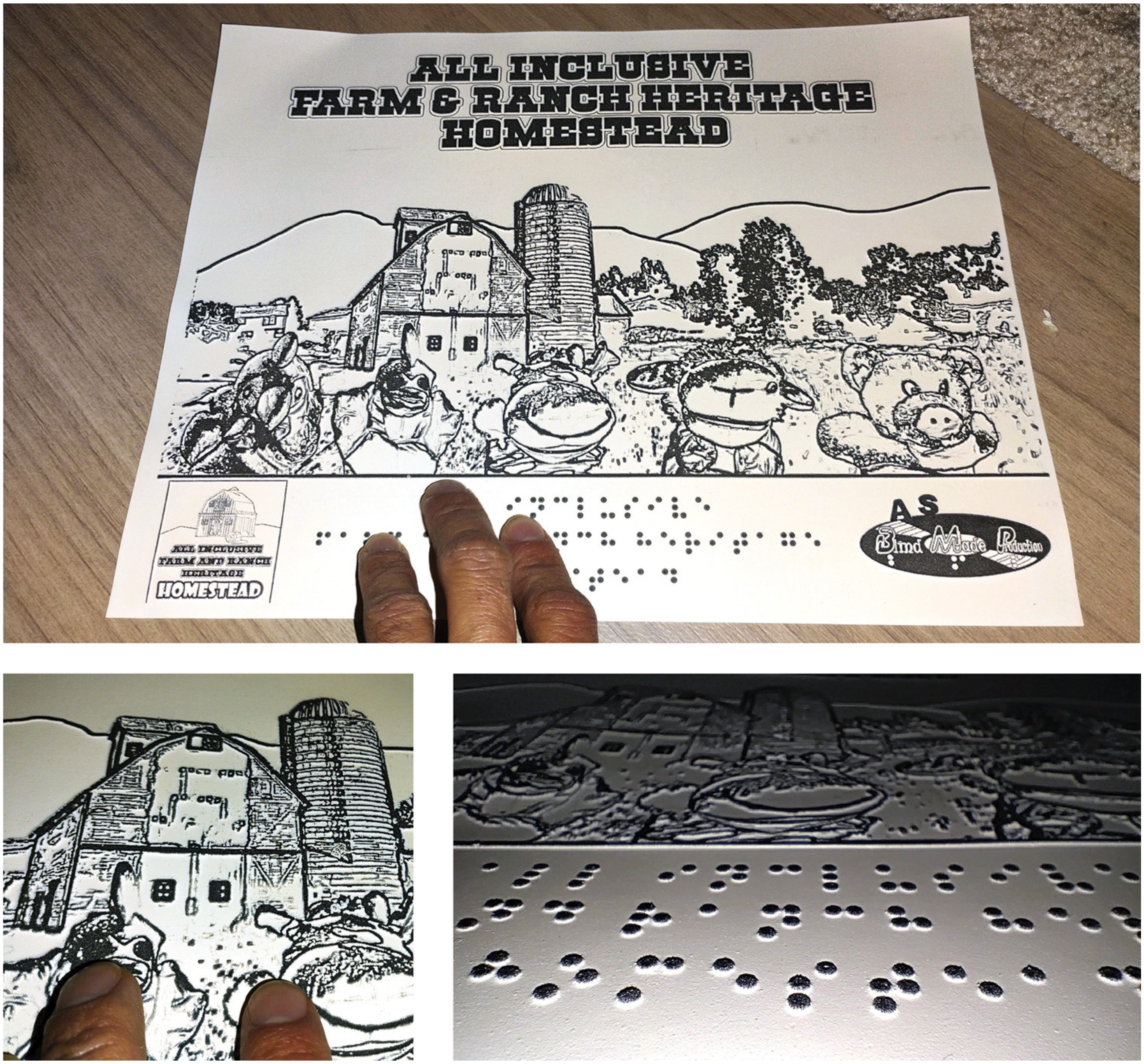

Figure 3: High tech approaches to making tactile graphics include microcapsule or "swell" paper. Swell paper is coated with particles that expand when heated. It can be printed or drawn on in grayscale, then swollen using a heat lamp that will heat the darker regions faster than the light. This graphic was made by P7, who designed the graphic and solicited help from the library which had a swell machine to reproduce it tactilely. The graphic includes a photo of a farm and ranch scene with raised print and braille.

(Not to mention *"how much space [an embosser] takes. It's noisy. It's not practical for people to have in their homes."* (P1)) Getting access could be a hurdle, e.g., P7 negotiated a *"one time deal"* to use his library's swell machine to produce tactile coloring pages.

The time required to make graphics shaped participant workflows. Crafting methods could produce graphics that were *"effective for the moment"* (P11), which sometimes *"did the job"* if what you needed was *"just a sketch"* (P3). Digital design tools could yield high fidelity results but with high time costs. P12 recalled using braille typesetting software to design a tactile graphic for embossing, meticulously making edits, before realizing *"okay now I've spent like half the day on this, and this isn't something that I need to be* *doing."* This tradeoff between graphic fidelity and time invested was marked among participants who didn't have easy access to high tech tools. For P1 to get a design embossed: *"I would have to go downtown and learn how to use the equipment, wait in line to be able to use the equipment, and then come back home, all to get a picture that anybody could go look at on the internet and see it in a heartbeat."* While high-fidelity tactile graphics are often desirable, the resources that must be expended to produce them can perpetuate the information disparity between sighted and BLV people.

Tools for tactile graphics are often not accessible to BLV users, or accessible only with great investment of time and skill, creating significant hurdles for BLV creators. To P10, *"if you are a blind teacher relying on a screen reader, you cannot create a tactile graphic* [using software for embossers]. *That is for the sighted TVIs* [teachers of the visually impaired] *of the world. There's nothing that makes that accessible."* Participants described some workarounds, such as expensive outsourcing (P7) or learning openSCAD (P4), to get around software inaccessibility, but highlighted that these did not provide equal access. Using tactile drawing software as a blind braillist, for example, *"you have to make a lot of calculations in your head, or have some kind of assisted way to help you"* (P4). As P12 found, popular braille transciption tools are an accessible means of laying out graphics for embossing but are built for word processing and lack image editing features, so *"if you make an adjustment, [...] then you redo everything"* (P12).

Inaccessibility led many participants to work with sighted collaborators. However, co-creating requires trust and an established shared knowledge base. P13 explained: *"I couldn't just hire somebody out of high school to help me with this stuff. I needed somebody that actually kind of knew how to use this software."* Yet, once these workflows were established, they often led to fulfilling collaborations, such as the well-established partnership between writer P1 and a sighted illustrator. Collaborations can also leverage complementary expertise. For example, P4's sighted colleague lays out the image, sharing it through the cloud with P4, who verifies the labels, tasking the embossing to his colleague, who returns it to P4 for review, *"making sure that I can interpret it just as my student would."* And P3 found meaningful and *"intuitive"* partnership by working with other blind designers: *"You know, someone creates something, you can all touch it, you can all give feedback. You can all define it together."*

Ultimately, participants found both high- and low-tech approaches valuable and often combined the two (e.g. through annotation). While some criticized the inconsistencies of crafting graphics, these methods remained a fallback for when higher-tech workflows were impractical. Furthermore, some found crafting more expressive than other methods: *"I might just start with using the embosser .... then adding some of my own texture to it"* (P8) using materials such as felt or tape.

4.2.4 *Considering tactile perception.*

When thinking about what makes a high quality tactile graphic, participants identified tactile understandability and aesthetics as key dimensions. Notably, when considering factors of tactile perception as designers, participants drew on their experiences as tactile graphics users, a perspective not well-represented in prior literature.

As tactile graphic designers, participants described frequent encounters with *"limitations of the space"* (P12). Designing for the tactile domain entails a commitment to a certain degree of detail, limited by the size and tactile acuity of hands and fingertips. While print may be visually legible at small font sizes, braille must be rendered at a standard size, typically larger than print: *"a huge math book in braille—that's like, 70 volumes"* (P14). Similarly, a tactile graphic *"demands [...] a coarse resolution"* (P13). For designers, this necessitates a choice between bulkiness or simplification. Large graphics preserve detail but become *"unwieldy"* (P14), to the point of being frustrating to use (P8). Therefore, participants typically opted to keep graphics *"as simple as they can be"* (P10). Teachers P8 and P10 shared their guiding questions for effective simplification—*"how overwhelmed is the student going to be [...and] are they going to able to glean what is needed?"* (P10)—and acknowledged the costs—*"at the same time, you know that, like, other kids are getting access to more information"* (P8). And though the central challenge of tactile design is *"efficiency of the conveyance"* (P13), for BLV designers in particular, the time taken to simplify a design has its own cost: *"a beautiful, nice art project"* that condenses information efficiently may take *"several days to create"* (P13).

Tactile graphics must also convey information about the 3D world in a 2.5D format that is intelligible to users who often have few visual points of reference. 2D graphical conventions often encode visual representations of the world: "*"sighted people are limited to only seeing what's straight in front of them"* (P1). P14 had experience encountering graphics *"drawn the way it would look to a visual person in 3D"*, which did not work for her as someone who had *"never seen 3D images before."* BLV tactile graphic designers must decide how much to engage with visual graphical conventions.

Participants also weighed when to use tactile design standards. Many handmade graphics are made with what P4 termed *"jazz musician implementation rules"*. However, teacher P10 warned that designing with a *"lack of consistency"* in style could leave readers unsure how to understand or orient themselves to a graphic. Even with standards in place, machine inconsistency means output can be variable. *"Sometimes your machine is hotter"* (P14), or your heat lamp malfunctions: *"you might overexpose the image, then the ink kind of swells up more than what it needs to then it kind of bursts"* (P7). P14 described exploring a graphic and wondering *"is that a tactile thing to indicate, or is that a 3D printer error?"*

Combining aesthetics, design, and print quality, participants reflected on what made a graphic enjoyable to use. P1 noted that *"there's a lot of tactile graphics out there that I put in the better than nothing category"*, due to their lack of contrast or unpleasant, rubbery feel. Knowing the aesthetic sense of graphic users helped guide many creators. P8 explained that if she knew students *"are into like feathers, or they're really into like glitter or things like that, like trying to incorporate that a little bit to get them more excited."* Similarly, P10 worked with the fact that *"there are students that are tactilely resistant to certain textures."* Curating graphics to meet the tactile aesthetic sense of their user was a crucial consideration for how useful and usable those graphics could be.

4.3 How BLV creators imagine better tools

When asked to speculate on the future of tactile graphics creation, interviewees articulated two primary desires: that the future of tactile creation will be inclusive and that it will be easier. Toward these objectives, participants had strong preferences about what kinds of tools could best support their tactile graphics making, from tools to automatically convert images into tactilely-intelligible forms, to improved access to common methods of graphics design and fabrication, to systems for sharing graphics widely.

4.3.1 Exploring automation. A number of participants imagined tools for automated visual-to-tactile conversion: translating images into formats capable of being rendered with, for example, an embosser or swell machine. Although such systems have been the subject of research and development, e.g. [20, 28, 31], only one participant mentioned using an automated system (P12, using the commercially available TMAP to generate a tactile street map).

Participants held multiple motivations for wanting automated tools: to access tactile graphics nearly *"instantly"* (P14), compared to current processes; to do so without sighted intervention (P13); and to generate diverse, personally useful graphics, from train route maps (P8) and aerial images of one's neighborhood (P13), to images from astronomy articles (P14) and *"weird-looking"* animals on YouTube (P3), to visualizations of blood sugar levels (P6) or geographic data (P13).

A commonly desired feature for automatic conversion tools was the ability to adjust the output toward improved legibility and usefulness. P14 explained, *"you can't just, like, take a printed image, send it through and there you go. There's [...] always tweaks that needed to happen in order to make the tactile image more understandable by touch,"* a process which designers currently accomplish manually. Participants desired having control over image processing not only for legibility's sake but also to make design choices, like *"the level of specificity"* (P14) of an image or data. Given that scale is an intrinsic challenge of tactile graphic design, participants imagined being able to have *"that choice, to be able to zoom in, so to speak"* (P14) by producing variations of a graphic with differing degrees of detail.

Participants imagined what interfacing with such a system would be like. Some had experience with tools like Be My AI, which support natural-language querying to generate image descriptions and to guide taking photographs. They imagined that future visual-to-tactile conversion tools could support image processing via natural language querying and commands:

> *"As a blind person, I would love to say, okay, tactile graphics software, make all the red raised up a little higher, [...] ask it questions about the image, and then create a tactile rendering of it myself as I need it. Because then I could highlight information that was important to me"* (P14)

Natural language interaction would require developing shared vocabulary for what it means to translate an image to a tactilely-legibile equivalent. *"There'd probably need to be some more agreement"* (P3) on the relationships between components of design and the tactility of the output.

It is worth noting that participants indicated that no one perfect tool can serve all tactile graphics making purposes. As P14 explained, *"Not only would I want to render graphics that already exist, in a tactile format, but I think it'd be really cool to be able to create my own tactile graphics and visual representations of things as I picture them"* (P14). For many participants, automation seemed especially promising for rendering currently inaccessible visual information. Communicating one's own ideas, however, seemed like a task requiring finer control than automated tools might allow—the kind of control that existing design and fabrication tools promise.

4.3.2 Expanding accessible input and output. Participants imagined accessibility improvements that would allow them to realize the kinds of graphics they desire with common tactile graphics making tools. As P2 put it, there are the tactile graphics she makes by hand, and then there are *"the ones I've made in my head—because I do that a lot."* Participants shared numerous concepts for tactile graphics that they had imagined but not yet made: a tactile task tracker (P2), mazes and games (P12), and a visualization of the ranges of musical instruments (P5). For most, the barrier between ideation and realization was accessibility of tools.

Software accessibility stood out as a major obstacle. Not only did makers seek access to software that was directly useful for editing graphics, but they also sought access to the underlying information needed to design maps, charts, and illustrations. P13, who encountered these access difficulties as a student of environmental science and geography, expressed his deep frustration that this remains an issue:

> *"What I'd like to see happen, first of all, is just an improvement in existing technology [...] so a blind person can use it. Like, that just seems a no brainer. Like, say, you know, the software that I was using for generating these maps, like, there's nothing, no reason why that stuff should not be accessible. That's just, like, bad design on the makers' part that it isn't accessible, that I can't just, like, jump onto it and start, you know, using my keyboard and doing what I need to do."* -P13

Beyond the general challenges of screen reader accessibility, participants desired improvements to the specific challenge of making graphics nonvisually. For example, P6 imagined expanding available commands, while P13 suggested possible functions to improve tactile map generation with existing GIS software, including programmatically modifying the characteristics of a set of points, or separating map layers into individually printable graphics with registration marks for physical realignment. Similarly, P4 envisioned a more intuitive drawing mode for tactile graphics software:

> *"You have a graphing cursor [...] you press maybe, like a modifier key, like Ctrl+left arrow, and you move [...] If you press Ctrl+left, you start not just moving, but actually graphing, or drawing, [...] You press Ctrl+down, and you draw again, down. You press Ctrl+right, you draw right. And you press Ctrl-up, and you just made a square."* (P4)

Other participants envisioned using analog tactile drawing (P3) or drawing via refreshable displays (P4) as input to other forms of fabrication, like simple paint programs (P1). P3 imagined the ability to *"perfect"* hand-drawn shapes, *"combining something really intuitive, like tactile sculpting or drawing [...] with some use of technology* *to [...] put things together in a way that's [...] more precise"* (P3). P8, who has been piloting the use of a refreshable tactile display in her classroom, was excited by the time-saving implications of real-time rendering:

> *"I think it's going to get to the point to where you can draw on the board, and there's a camera on the device, and [...] as you're writing on the board or drawing something on the board, it's supposed to pop up on the screen. So that would be, monumental, because [...] I wouldn't have to do, like, preparation a week in advance of math class. I could just teach math class, and as I'm doing things on the board, it just shows up on their device."* (P8)

Participants often reached for the example of pin-based refreshable tactile displays to exemplify what they hoped for and valued in future tactile graphics output (P14): speed, portability (to a degree), compatibility with devices people already have, and having the ability to *"zoom in and out"* (P12) in detail. They imagined using dynamic displays to produce time-varying information, like a weather system—*"how it's moving, where it might hit"* (P11).

On the whole, participants described enthusiasm around having more options for output, from 3D printing to haptic displays. P9 imagined interoperable design files that would make it easy to create an embossed, swell-form, or 3D printed image from a single design. Teacher P8 expressed a desire for more expressive machine-made graphics, especially for *"kids with neuropathy, or really young kids that are still learning tactile discrimination"* who have difficulty distinguishing textures on embossed graphics. She imagined distinct textures, even mixed materials:

> *"some sort of device that could, like, incorporate, like, more variety of textures, [...] using different mediums to represent different things, you know, like having some parts be plastic and some parts be felt."* (P8)

These diversity of proposals for accessible interactions reflects a diversity of preferences and a desire for options: *"Every blind person's experience, obviously, is very different"* (P4).

4.3.3 Sharing the labor. Tactile graphics creation can be a time-intensive practice, especially for blind and low vision practitioners. Participants imagined systems that could reduce redundant labor by leaning into *interdependent* practices among networks of tactile graphics makers [2]. Teachers of the blind already swap services (P10) and actual graphics *"all the time"* (P8). To facilitate similar sharing between parties that are not co-located, participants imagined systems for physically exchanging graphics: *"There's a National Library [Service] for the blind, right? Why isn't there a national library of tactile graphics?"* (P2)

Others imagined digital databases for sharing design files. While some such repositories exist [8, 19], a portion of interviewees had never heard of them—like P9: *"as far as I know, there's no such community sharing these files."* P4, who *was* a regular user of catalogs of tactile graph templates, called the inconsistency of metadata a *"curse:" "It's just people not aware that there are going to be blind people looking for these designs [...] People just assume that you need full sight [...to] look up information or use types of graphics."* P4 imagined databases with thorough, useful image descriptions that would aim to serve BLV users specifically.

Participants were especially interested in being able to *contribute* new tactile graphics to such databases:

> *"So if someone creates a tactile graphic to do something out of a specific textbook in my state, that tactile graphic can then be uploaded into the tactile graphics library [...] and accessed by anyone in the world [...] People should be able to take an image from the shared library, and then they do need to be able to make changes, mark it up, add labels, all of the things that they need to do."* (P10)

P10 emphasized the importance of being able to annotate or modify images, to *"put that image back out there, marked up in this way so that someone else doesn't have to do that again"*, comparing the idea to the educational resource marketplaces that *"work both ways"* (P10).

Participants also speculated about how to distribute the labor of *producing* graphics. Given that the costs of individually acquiring fabrication equipment were deeply impractical for all participants, some voiced interest in outsourcing fabrication to organizations with the necessary equipment. Some participants pointed to free mailing services for the blind through the US Postal Service as an example of existing infrastructure that could be utilized to support on-demand fabrication services.

5 Discussion

Grounded in our findings, we present three overarching design goals for tactile graphics production systems: (1) the materials and equipment to make those graphics should be accessible to blind and low vision people, (2) they should support ubiquitous availability of tactile graphics, and (3) they should promote diversity and expressivity of tactile media as a whole.

5.1 Tactile graphics making should be accessible

Tactile graphics creation needs to be accessible to blind and low vision people themselves. The gaps in access to graphical information available to blind and low vision people are wide. Yet BLV people who hope to address those gaps through tactile graphics—who know best what they need from those graphics and who often bring embodied knowledge as readers—must pour significant labor into navigating the most common tools of design and production. Additionally, making tactile graphics firsthand can be a highly meaningful activity, tied to larger ideas about the right to participate in the world. It is imperative that blind and low vision people have access to the tools they need to design and produce, if they so choose.

Making progress towards inclusion means improving the accessibility of the most common tools used today for designing and producing tactile graphics. Many image editing tools have poor or no screen-reader accessibility. While tools primarily used for visual design are often not assumed to be priorities for screen reader accessibility, BLV people desire access to these tools [40], and many image editors have features that are also highly relevant to tactile graphics design. Expanding the available options for providing input to image editing tools – e.g., through free-hand drawing, with keyboard keystrokes, or through natural language description, as in [26] – and the degree to which customization is supported could accommodate a wider range of design processes. As participants highlighted, such features requires thoughtful interaction design for useful and usable nonvisual feedback . We consider these accessibility improvements to existing tools to be the low-hanging fruit for lowering the threshold to tactile graphics production.

The practices of blind and low vision makers should set the direction for future tactile graphics-making tools. Our participants had clear ideas about the kinds of tools they needed. As new tools continue to be developed, from refreshable tactile displays to automatic visual-to-tactile conversion systems, BLV expert users should be involved not only in evaluating those tools but in designing and prototyping them, starting at the earliest stages of development [9].

Moving toward inclusive tactile graphics making also means supporting the formation of communities of practice. Here, we find that the issue of making tactile graphics intersects with framings of *independence* and *interdependence*. The independence to make one's own choices and to participate in public life has been a guiding value in movements for disability rights [2]. Similarly, we find that making tactile graphics independently is a desire and source of pride for many. At the same time, we find that BLV makers desire systems for sharing graphics and knowledge that rely on one another's strengths and labor. Rather than setting autonomy as the sole goal, they acknowledge that *interdependent* relationships can be necessary and desirable. Prior work, e.g. by Bennett et al., has positioned interdependence as a useful and disability justice-aligned orientation for accessibility research, one which can help us "anticipate the awkward aspects of social interactions and the roles of policy, labor, and materials that shape infrastructural-level decisions" [2]. We find that tactile graphics design and production typically involves informal networks, connecting contributors with varying resources, expertise, and experiences. Strengthening existing networks and designing to support the formation of new networks can allow us to embrace interdependence as a "political technology" [15] and to make the accessibility of tactile graphics creation less vulnerable to the comings and goings of individual actors.

Finally, making tactile graphics production accessible is not just a question of tools and community, but also one of educational opportunities. Translating the 3D world to a 2D or 2.5D page requires tactile graphical literacy. Encouraging early and persistent tactile experiences, promoting curricula for graphicacy, and ensuring that equipment and services are available after K-12 education are key.

5.2 Tactile graphics should be ubiquitous

The tactile graphics our participants encountered were described as precious. We argue that they must become ubiquitous. As participants attested, there is a wide gap between near constant access to pictorial and spatial information for sighted people on one hand and occasional opportunities to read a tactile map on the other. Our findings show that lack of access to tactile graphics can have compounding, circular effects; lack of access makes it hard to gain tactile graphics reading skills (graphicacy), which in turn can make making tactile graphics seem irrelevant.

We argue that there need to be many levels of tactile graphics—quick inexpensive sketches, high-fidelity graphics, and everything in between. Crucially, having quick sketches isn't a replacement or interchangeable with high-quality graphics. Neither is a text description of an image. BLV people should not only be excluded from accessing quality graphical information due to challenges in graphics creation. Rather, we need to acknowledge the labor and cost inequities that come with making tactile graphics and actively work on methods to counteract them.

Making tactile graphics ubiquitous can partially be addressed by improving tactile graphics production workflows. Many tactile graphics production methods have remained unchanged for decades, and there are myriad ways in which these laborious and manual techniques (many of which rely on sighted producers) could be streamlined and improved. However, making tactile graphics design and manufacturing easier will not on its own improve the ubiquity of tactile graphics. Making tactile graphics ubiquitous requires commitments from many parties to dedicate time, money, and other resources to production and dissemination at scale.

5.3 Tactile graphics should be expressive

In addition to the prevalence and accessibility of tactile graphics, the legibility and expressiveness of tactile graphics are major factors in whether blind and low vision participants found it worthwhile to use them at all, much less make them. Effectiveness of graphics also affects choice of fabrication method. When tactile graphics creators turn to collage, either by choice or necessity, they are able to use a range of distinct and satisfying textures currently not achievable by other means. But in doing so, they are unable to take advantage of the replicability and speed of graphics produced using machines. Just as achieving finer and finer resolution is the pinnacle for research on pin-based tactile displays, so too should tactile expressivity be a priority for the continued development of tactile graphics fabrication methods.

Developers of novel tactile graphics fabrication approaches should focus on pushing output to its tactilely expressive brink and should characterize what those limits are, for designers' benefit. Someone sitting down to design an image on microcapsule paper should have access to swatches that convey the expressive limits of the medium rather than needing to discover those anew.

Interviewees often spoke of the struggles of dealing with inconsistent results and not knowing how to rectify them. We should promote practices like producing test swatches and promoting understanding of machine maintenance and calibration [46]. Supporting the inclusion of BLV designers means equipping them with both tools that eliminate costly reinvention and tools that promote understanding of production processes.

Ultimately, the medium of tactile graphics is still at its relative infancy. Much work remains to chart the design space that tactile graphics encompass, and to provide tools that enable expressive design in that space. When creating new resources, anticipating an evolving field will be crucial to avoiding pitfalls and waste.

6 Tactile Graphics Futures

To further explore possibilities for inclusive tactile graphics creation, we extrapolate from our design goals and from participants' speculations to present three design fictions for future tactile graphics systems. HCI research engages with design fiction to allow people to imagine engaging with technologies before they exist, allowing for exploration of concepts without concern for feasibility [1, 4, 23], specificity [5], eliciting opinions from stakeholders [11, 38], or critiquing the futures systems may engender [39, 41]. The design fictions below are not necessarily intended to be technically feasible or practical; in fact, they intentionally move away from "ableist failure[s] of imagination" [22] to imagine futures in which access to tactile graphics making has compounding, positive effects. These fictions offer a speculative interpretation of participants' desires. We hope they can help mobilize HCI systems and fabrication researchers to contribute to this area of research and translate these ideas into reality.

6.1 A Platform for Sharing Tactile Graphics

Robin returns home from school, inspired by stories they've heard about sea creatures: eight-legged octopi, sea sponges shaped like cakes, and corals that look like brains. They log on to TheTactileBay, a platform for sharing tactile graphics. Searching for octopi yields millions of results, and Robin explores the tags: octopi in their habitats, close-ups of their suction cupped arms, and diagrams of how they swim. Robin selects a few graphics to print and read, including an anatomical overview, an image of baby octopi hatching, and an image of an octopus using a rock as a tool. They specify the type of printer they have at home to download the appropriate print file. Their printer creates the images in seconds and Robin explores the contours, textures, and relative size of the creatures. Many of their favorite graphics are made by the user MolluscScientist, a researcher on the other side of the world who has uploaded realistic graphics of the many species they work with. Their graphics are layered, so Robin can explore the information sequentially—first the contours of major shapes and their labels, then the smaller shapes and how they are contained, then the different textures. Robin is also enchanted by wildly different graphics, namely beautiful octopus-inspired art by users like OctoArtist and DeepSeaDreamer. To read more of these graphics, Robin also follows the hashtag #deepseafiction, which creates of feed of new tactile art that's updated many times per day.

Exhilarated by what they've learned, Robin's imagination starts running wild. They start sketching their own tactile graphics using their embossing tools and regular sheets of paper. They digitize their quick sketch with their cellphone to share in the #deepseafiction community. A community member in another country is intrigued and views the image. They use a refreshable pin display, but the automated format conversion of TheTactileBay makes sharing easy. This new person discusses the color-changing camouflage with Robin, and they start sketching tactile puzzles for each other, hiding their octopi in similar textural backgrounds and deep sea locations. The "remix" button lets them easily reuse and recombine existing graphics in their puzzles. They discuss elements they touched—are these markings on the skin, or perhaps breathing gills?

6.2 Tactile Graphics Equipment Limited

Robin's printer is one of the machines made by Tactile Graphics Equipment Limited, the HomeTac3000. The HomeTac3000 is designed for use in a bedroom or office: it is quiet, prints on inexpensive letter-sized paper, is exceedingly robust, and costs less than 200 dollars. Robin mainly uses it from their laptop, but the HomeTac3000 also has a voice assistant interface. Robin talks to the voice assistant mainly if they quickly need a print of a map: "Hey HomeTac3000, print me a map to that new taco food truck" is a command they issued recently.

Robin's teacher Dr. River has the TacXPro, a larger machine that can produce tactile graphics of many sizes, on paper as well as on more robust materials like aluminum and plastic sheets. Dr. River used it to make various maps of Robin's school: a labeled paper map of the classroom and its supplies for each student to keep in their desk; a durable, foldable felt campus map that new students carry around as they learn to navigate campus; and finally a four foot wide detailed sculptural map of the school and surrounding area that is proudly displayed in the office. When the students decide to rearrange the desks in the classroom, it takes Dr. River a few minutes to redesign the seating chart in the classroom map and seconds to print new maps for all thirty of Robin's classmates.

Tactile Graphics Equipment Limited has accessible documentation of their equipment, and the school handy person has no trouble maintaining the school's printers, when paper gets jammed on occasion, or even the one time students tried to use the TacXPro's TacCopy function to reproduce the school pet hamster. TGEL's machines themselves are open-source hardware, and were originally based on inexpensive 3D printer designs. They owe their robust nature and accessible interfaces to many community-contributed design tweaks. Some of these tweaks improve the overall functionality, but others also tailor TGEL's designs to local supply chains.

TGEL also makes the OpTaCon Tablet. Inspired by the original, long-discontinued OpTaCon, the tablet supports OPtical-to-TActile-CONversion in real time. The tablet can capture images and immediately render them on its vibro-tactile screen. The user can cycle through different modes of rendering the images, specialized for text, small objects, landscapes, and more. The City Zoo has a fleet of OpTaCons, and on a recent field trip Robin used them to look at fluffy red pandas waking up from a nap and noshing on long thin reeds of bamboo.

6.3 Tactile Graphics Design Software

MolluscScientist uses TactileIllustrator to make most of their graphics, for work and for fun. This software has features common in graphic design for importing images, editing vectors and pixels, and outputting a range of known tactile graphics formats. It has several built-in styles which it applies using common style transfer tools, making it simple to automate some of the work of processing visual data into tactile graphics. MolluscScientist also has the TactileIllustrator SketchPad, an inexpensive interactive pin display shaped like a trackpad that quickly renders graphics and accepts stylus input. The software and tactile preview makes operations trivial that MolluscScientist remembered to be previously laborious when using ancient word processing tools as ad hoc tactile graphics editors, such as resizing, rotating, and moving elements.

TactileIllustrator can also work with more sophisticated printers to render expressive textures and tactile experiences far beyond what is possible on the SketchPad, bringing the deep sea creatures they study to life.

6.4 Reflection and Limitations

Writing these design fictions that echo our design goals of ubiquitous and expressive tactile graphics and accessible ways to design them is joyous, as it is easy to imagine a thriving tactile graphics future. In contrast with many other speculative systems, our fictions aren't dystopian and feel achievable, and we are hopeful that the futures we describe are near. After all, the systems we describe are similar to existing and established versions made for sharing other kinds of content: TheTactileBay isn't dissimilar to Thingiverse, the platform for people to share 3D prints, the HomeTac3000 or the TacXPro are not that different from existing printer equipment, and TactileIllustrator isn't dissimilar to existing vector graphics design software. Tablets like the OpTaCon are active areas of research.

However, it is easy to imagine that this near future could never come at all. Volunteer burnout, immutable systems, and accessibility not being a priority are familiar disappointments. We need concerted effort from systems researchers and accessibility experts to prioritize accessibility and inclusion in tactile graphics to make such systems possible soon.

One additional limitation of this study is its potential bias toward tactile graphics enthusiasts. We intentionally recruited from specialist groups like TAGS to find eligible interviewees, which may have yielded respondents especially enthusiastic about and experienced with tactile graphics creation. This targeted recruitment may obscure that many blind and low vision people do not make or use tactile graphics on a regular basis. The desires for graphics-rich futures that we share in this paper reflect the desires of our participants, not necessarily all blind and low vision populations.

7 Conclusion

In this paper, we described the experiences and desired futures of 14 blind and low vision (BLV) tactile graphics creators. We found that there are compounding challenges associated with tactile graphics, including access to graphics, ability to read them, and the ability to design them. Our participants navigated these challenges creatively but laboriously while imagining better futures. We distilled the following design goals from their experiences: in the future, tactile graphics should be ubiquitous, expressive, and making them should be accessible to BLV people. Finally, we described fictional systems for tactile graphics, demonstrating online sharing, easy production, and accessible design tools, calling HCI researchers to action to co-create this possible future.

Acknowledgments

The authors would like to thank the interview participants for their time and effort. The authors also thank the National Braille Press for their stewardship of the Princeton Braillists' collection. This research was supported by Apple Inc., NSF Grants 2339273 and DGE-2140004, and by the University of Washington's CREATE center. Any views, opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and should not be interpreted as reflecting the views, policies or position, either expressed or implied, of Apple Inc.

Conflict of interest disclosure: Leah Findlater is also employed by and has a conflict of interest with Apple Inc.

References

[1] Michelle Annett, Tovi Grossman, Daniel Wigdor, and George Fitzmaurice. 2019. Exploring and Understanding the Role of Workshop Environments in Personal Fabrication Processes. *ACM Transactions on Computer-Human Interaction* 26, 2, Article 10 (Mar. 2019), 43 pages. doi:10.1145/3301420

[2] Cynthia L. Bennett, Erin Brady, and Stacy M. Branham. 2018. Interdependence as a Frame for Assistive Technology Research and Design. In *Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '18)*. Association for Computing Machinery, New York, NY, USA, 161–173. doi:10.1145/3234695.3236348

[3] Cynthia L. Bennett, Abigale Stangl, Alexa F. Siu, and Joshua A. Miele. 2019. Making Nonvisually: Lessons from the Field. In *Proceedings of the 21st International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '19)*. Association for Computing Machinery, New York, NY, USA, 279–285. doi:10.1145/3308561.3355619

[4] Mark Blythe, Kristina Andersen, Rachel Clarke, and Peter Wright. 2016. Anti-Solutionist Strategies: Seriously Silly Design Fiction. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (San Jose, California, USA) *(CHI '16)*. Association for Computing Machinery, New York, NY, USA, 4968–4978. doi:10.1145/2858036.2858482

[5] Mark Blythe and Enrique Encinas. 2016. The Co-ordinates of Design Fiction: Extrapolation, Irony, Ambiguity and Magic. In *Proceedings of the 2016 ACM International Conference on Supporting Group Work* (Sanibel Island, Florida, USA) *(GROUP '16)*. Association for Computing Machinery, New York, NY, USA, 345–354. doi:10.1145/2957276.2957299

[6] Jens Bornschein, Denise Bornschein, and Gerhard Weber. 2018. Comparing Computer-Based Drawing Methods for Blind People with Real-Time Tactile Feedback. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18)*. Association for Computing Machinery, New York, NY, USA, 1–13. doi:10.1145/3173574.3173689

[7] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative research in psychology* 3, 2 (2006), 77–101.

[8] BTactile. 2024. BTactile homepage. https://btactile.com/

[9] Matthew Butler, Leona M Holloway, Samuel Reinders, Cagatay Goncu, and Kim Marriott. 2021. Technology Developments in Touch-Based Accessible Graphics: A Systematic Review of Research 2010-2020. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, Yokohama Japan, 1–15. doi:10.1145/3411764.3445207

[10] Tingyu Cheng, Zhihan Zhang, Bingrui Zong, Yuhui Zhao, Zekun Chang, Yejun Kim, Clement Zheng, Gregory D. Abowd, and HyunJoo Oh. 2023. SwellSense: Creating 2.5D interactions with micro-capsule paper. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany) *(CHI '23)*. Association for Computing Machinery, New York, NY, USA, Article 424, 13 pages. doi:10.1145/3544548.3581125

[11] EunJeong Cheon and Norman Makoto Su. 2018. Futuristic Autobiographies: Weaving Participant Narratives to Elicit Values around Robots. In *Proceedings of the 2018 ACM/IEEE International Conference on Human-Robot Interaction* (Chicago, IL, USA) *(HRI '18)*. Association for Computing Machinery, New York, NY, USA, 388–397. doi:10.1145/3171221.3171244

[12] Lilian De Greef, Dominik Moritz, and Cynthia Bennett. 2021. Interdependent Variables: Remotely Designing Tactile Graphics for an Accessible Workflow. In *The 23rd International ACM SIGACCESS Conference on Computers and Accessibility*. ACM, Virtual Event USA, 1–6. doi:10.1145/3441852.3476468

[13] Polly Edman. 1992. *Tactile Graphics.* American Foundation for the Blind, New York, NY.

[14] John A. Gardner. 1996. Tactile graphics: an overview and resource guide. *Information Technology and Disabilities* 3 (1996). https://api.semanticscholar.org/CorpusID:58659489

[15] Aimi Hamraie and Kelly Fritsch. 2019. Crip Technoscience Manifesto. *Catalyst: Feminism, Theory, Technoscience* 5, 1 (April 2019), 1–33. doi:10.28968/cftt.v5i1.29607 Number: 1.

[16] Liang He, Zijian Wan, Leah Findlater, and Jon E. Froehlich. 2017. TacTILE: A Preliminary Toolchain for Creating Accessible Graphics with 3D-Printed Overlays and Auditory Annotations. In *Proceedings of the 19th International ACM SIGACCESS Conference on Computers and Accessibility* (Baltimore, Maryland, USA) *(ASSETS '17)*. Association for Computing Machinery, New York, NY, USA, 397–398. doi:10.1145/3132525.3134818

[17] Megan Hofmann, Kelly Mack, Jessica Birchfield, Jerry Cao, Autumn G Hughes, Shriya Kurpad, Kathryn J Lum, Emily Warnock, Anat Caspi, Scott E Hudson, and

Jennifer Mankoff. 2022. Maptimizer: Using Optimization to Tailor Tactile Maps to Users Needs. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 592, 15 pages. doi:10.1145/3491102.3517436

[18] Leona Holloway, Swamy Ananthanarayan, Matthew Butler, Madhuka Thisuri De Silva, Kirsten Ellis, Cagatay Goncu, Kate Stephens, and Kim Marriott. 2022. Animations at Your Fingertips: Using a Refreshable Tactile Display to Convey Motion Graphics for People who are Blind or have Low Vision. In *Proceedings of the 24th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '22)*. Association for Computing Machinery, New York, NY, USA, 16 pages. doi:10.1145/3517428.3544797 event-place: Athens, Greece.

[19] American Printing House. 2019. The Tactile Graphics Image Library: Helping Students Succeed. https://www.aph.org/the-tactile-graphics-image-library-helping-students-succeed/

[20] Chandrika Jayant, Matt Renzelmann, Dana Wen, Satria Krisnandi, Richard Ladner, and Dan Comden. 2007. Automated tactile graphics translation: in the field. In *Proceedings of the 9th international ACM SIGACCESS conference on Computers and accessibility (Assets '07)*. Association for Computing Machinery, New York, NY, USA, 75–82. doi:10.1145/1296843.1296858

[21] Nicole Johnson, Tom Yeh, and Ann Cunningham. 2022. Low-Cost Tactile Coloring Page Fabrication on a Cutting Machine: Assembly and user experiences of cardstock-layered tangible pictures. In *Proceedings of the 24th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '22)*. Association for Computing Machinery, New York, NY, USA, 1–5. doi:10.1145/3517428.3551353

[22] Alison Kafer. 2013. Feminist, Queer, Crip. *Indiana UP* (2013).

[23] Jeeeun Kim, Haruki Takahashi, Homei Miyashita, Michelle Annett, and Tom Yeh. 2017. Machines as Co-Designers: A Fiction on the Future of Human-Fabrication Machine Interaction. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (Denver, Colorado, USA) *(CHI EA '17)*. Association for Computing Machinery, New York, NY, USA, 790–805. doi:10.1145/3027063.3052763

[24] Jeeeun Kim and Tom Yeh. 2015. Toward 3D-Printed Movable Tactile Pictures for Children with Visual Impairments. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (Seoul, Republic of Korea) *(CHI '15)*. Association for Computing Machinery, New York, NY, USA, 2815–2824. doi:10.1145/2702123.2702144

[25] Richard E. Ladner, Melody Y. Ivory, Rajesh Rao, Sheryl Burgstahler, Dan Comden, Sangyun Hahn, Matthew Renzelmann, Satria Krisnandi, Mahalakshmi Ramasamy, Beverly Slabosky, Andrew Martin, Amelia Lacenski, Stuart Olsen, and Dmitri Groce. 2005. Automating tactile graphics translation. In *Proceedings of the 7th international ACM SIGACCESS conference on Computers and accessibility*. ACM, Baltimore MD USA, 150–157. doi:10.1145/1090785.1090814

[26] Seonghee Lee, Maho Kohga, Steve Landau, Sile O'Modhrain, and Hari Subramonyam. 2024. AltCanvas: A Tile-Based Editor for Visual Content Creation with Generative AI for Blind or Visually Impaired People. In *Proceedings of the 26th International ACM SIGACCESS Conference on Computers and Accessibility* (St. John's, NL, Canada) *(ASSETS '24)*. Association for Computing Machinery, New York, NY, USA, Article 70, 22 pages. doi:10.1145/3663548.3675600

[27] Wenhao Y. Luebs, Garreth W. Tigwell, and Kristen Shinohara. 2024. Understanding Expert Crafting Practices of Blind and Low Vision Creatives. In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI EA '24)*. Association for Computing Machinery, New York, NY, USA, Article 346, 8 pages. doi:10.1145/3613905.3650960

[28] Joshua A. Miele, Steven Landau, and Deborah Gilden. 2006. Talking TMAP: Automated generation of audio-tactile maps using Smith-Kettlewell's TMAP software. *British Journal of Visual Impairment* 24, 2 (May 2006), 93–100. doi:10.1177/0264619606064436 Publisher: SAGE Publications Ltd.

[29] National Braille Press. 2017. The Road from Princeton to Boston: The Princeton Braillists and an Enduring Legacy. https://nationalbraillepress.wordpress.com/2017/06/16/the-road-from-princeton-to-boston-the-princeton-braillists-and-an-enduring-legacy/, accessed 2024.

[30] Braille Authority of North America. 2022. Codebooks and Guidelines. https://www.brailleauthority.org/publications-area

[31] Athina Panotopoulou, Xiaoting Zhang, Tammy Qiu, Xing-Dong Yang, and Emily Whiting. 2020. Tactile line drawings for improved shape understanding in blind and visually impaired users. *ACM Trans. Graph.* 39, 4, Article 89 (aug 2020), 13 pages. doi:10.1145/3386569.3392388

[32] Perkins School for the Blind. 2024. Creating tactile graphics and embossed braille using a Cricut. https://www.perkins.org/resource/creating-tactile-graphics-and-embossed-braille-using-cricut/

[33] Mahika Phutane, Julie Wright, Brenda Veronica Castro, Lei Shi, Simone R. Stern, Holly M. Lawson, and Shiri Azenkot. 2022. Tactile Materials in Practice: Understanding the Experiences of Teachers of the Visually Impaired. *ACM Trans. Access. Comput.* 15, 3 (July 2022), 17:2–17:34. doi:10.1145/3508364 Place: New York, NY, USA Publisher: Association for Computing Machinery.

[34] Lauren Race, Chancey Fleet, Joshua A. Miele, Tom Igoe, and Amy Hurst. 2019. Designing Tactile Schematics: Improving Electronic Circuit Accessibility. In *Proceedings of the 21st International ACM SIGACCESS Conference on Computers and Accessibility* (Pittsburgh, PA, USA) *(ASSETS '19)*. Association for Computing Machinery, New York, NY, USA, 581–583. doi:10.1145/3308561.3354610

[35] Lauren Race, Chancey Fleet, Danielle Montour, Lindsay Yazzolino, Marco Salsiccia, Claire Kearney-Volpe, Sheri Wells-Jensen, and Amy Hurst. 2023. Designing While Blind: Nonvisual Tools and Inclusive Workflows for Tactile Graphic Creation. In *The 25th International ACM SIGACCESS Conference on Computers and Accessibility*. ACM, New York NY USA, 1–8. doi:10.1145/3597638.3614546

[36] Lauren Race, Claire Kearney-Volpe, Chancey Fleet, Joshua A. Miele, Tom Igoe, and Amy Hurst. 2020. Designing Educational Materials for a Blind Arduino Workshop. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems (CHI EA '20)*. Association for Computing Machinery, New York, NY, USA, 1–7. doi:10.1145/3334480.3383055

[37] Lauren Race, Joshua A Miele, Chancey Fleet, Tom Igoe, and Amy Hurst. 2020. Putting Tools in Hands: Designing Curriculum for a Nonvisual Soldering Workshop. In *Proceedings of the 22nd International ACM SIGACCESS Conference on Computers and Accessibility* (Virtual Event, Greece) *(ASSETS '20)*. Association for Computing Machinery, New York, NY, USA, Article 78, 4 pages. doi:10.1145/3373625.3418011

[38] Jeba Rezwana and Mary Lou Maher. 2023. User Perspectives on Ethical Challenges in Human-AI Co-Creativity: A Design Fiction Study. In *Proceedings of the 15th Conference on Creativity and Cognition* (Virtual Event, USA) *(C&C '23)*. Association for Computing Machinery, New York, NY, USA, 62–74. doi:10.1145/3591196.3593364

[39] Valkyrie Savage, Sarah Homewood, and Irina Shklovski. 2023. Objectify: Better Living Through Anticipatory, Just-for-you 3D Printing!. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany) *(CHI EA '23)*. Association for Computing Machinery, New York, NY, USA, Article 418, 8 pages. doi:10.1145/3544549.3582748

[40] Anastasia Schaadhardt, Alexis Hiniker, and Jacob O. Wobbrock. 2021. Understanding Blind Screen-Reader Users' Experiences of Digital Artboards. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '21)*. Association for Computing Machinery, New York, NY, USA, Article 270, 19 pages. doi:10.1145/3411764.3445242

[41] Britta F. Schulte, Paul Marshall, and Anna L. Cox. 2016. Homes For Life: A Design Fiction Probe. In *Proceedings of the 9th Nordic Conference on Human-Computer Interaction* (Gothenburg, Sweden) *(NordiCHI '16)*. Association for Computing Machinery, New York, NY, USA, Article 80, 10 pages. doi:10.1145/2971485.2993925

[42] Lei Shi, Ross McLachlan, Yuhang Zhao, and Shiri Azenkot. 2016. Magic Touch: Interacting with 3D Printed Graphics. In *Proceedings of the 18th International ACM SIGACCESS Conference on Computers and Accessibility* (Reno, Nevada, USA) *(ASSETS '16)*. Association for Computing Machinery, New York, NY, USA, 329–330. doi:10.1145/2982142.2982153

[43] Alexa F. Siu, Son Kim, Joshua A. Miele, and Sean Follmer. 2019. shapeCAD: An Accessible 3D Modelling Workflow for the Blind and Visually-Impaired Via 2.5D Shape Displays. In *The 21st International ACM SIGACCESS Conference on Computers and Accessibility*. ACM, Pittsburgh PA USA, 342–354. doi:10.1145/3308561.3353782

[44] Abigale Stangl, Ann Cunningham, Lou Ann Blake, and Tom Yeh. 2019. Defining Problems of Practices to Advance Inclusive Tactile Media Consumption and Production. In *Proceedings of the 21st International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '19)*. Association for Computing Machinery, New York, NY, USA, 329–341. doi:10.1145/3308561.3353778

[45] Abigale Stangl and Tom Yeh. 2017. Making for Graphicacy and Media and Information Literacy with People Who are Blind and Visually Impaired. In *2017 SIGUSE Symposium Abstracts (SIGUSE)*. Association for Information Science and Technology, Roseville, MN, 1–3.

[46] Hannah Twigg-Smith, Jasper Tran O'Leary, and Nadya Peek. 2021. Tools, Tricks, and Hacks: Exploring Novel Digital Fabrication Workflows on# PlotterTwitter. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 1–15.

[47] Jaroslaw Wiazowski. 2013. Creating tactile images - decision making process. In *Proceedings of the 7th International Convention on Rehabilitation Engineering and Assistive Technology* (Gyeonggi-do, South Korea) *(i-CREATe '13)*. Singapore Therapeutic, Assistive & Rehabilitative Technologies (START) Centre, Midview City, SGP, Article 58, 4 pages.

[48] Maria Fernanda Zuniga-Zabala and John Alexis Guerra-Gomez. 2022. Lessons Learned Building Low-Cost DIY Tactile Graphics and Conducting a Tactile Drawing Club in Colombia During COVID-19. In *Extended Abstracts of the 2022 CHI Conference on Human Factors in Computing Systems (CHI EA '22)*. Association for Computing Machinery, New York, NY, USA, 1–10. doi:10.1145/3491101.3503559