Tactile Media Consumption and Production for and By People who are Blind and Visually Impaired: A Design Research Investigation

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ABSTRACT

Stangl, Abigale Jane (Ph.D., Technology Media and Society)

Tactile Media Consumption and Production for and By People who are Blind and Visually Impaired: A Design Research Investigation

Thesis directed by Prof. Tom Yeh

The aim of this dissertation is to bring to light factors that affect how people who are blind or visually impaired (BVI) access, consume, design and produce with different types of tactile media for themselves or for others who are also BVI. Toward the goal of creating equity within the media and information landscape and beyond, this dissertation presents three interventionist studies to 1) identify the considerations and/or practices that people who are BVI engage in when consuming tactile media, producing (making, creating, designing) tactile media, and teaching with tactile media, and 2) identify design strategies that can be implemented to address the factors that limit BVI people's tactile media consumption, creation, and instruction practices. Study 1 presents a user-centered design process that resulted in the creation of a 3D printed design probe, which solicited feedback from 28 parents, teachers, and other stakeholders about their familiarity with tactile pictures generally, and the prospect of 3D printing as a tactile media production technology. Study 2 presents a design ethnography focused on identifying how different stakeholder groups approach the task of designing tactile media; 67 community stakeholders representing six different stakeholder groups participated. Study 3 presents a Research Practice Partnership that designed and implemented three "Tactile Art and Graphics Symposia," during which 41 BVI and 43 sighted individuals gathered to discuss the state of

inclusion in tactile art and tactile graphics consumption and production. Findings from this study revealed five problems of practice impacting how people are positioned to engage in the consumption, production, and instruction of tactile media. This dissertation contributes important insights about the lived experiences and practices of people, BVI and sighted, who are using, creating, and instructing with tactile media for themselves and others.

DEDICATION

I dedicate this work to all of the people who have been told that they can not or should not do something because of their (dis)ability and to every person who works tirelessly to create equitable experiences for all people to express their creative, spiritual, and intellectual geniuses.

ACKNOWLEDGMENTS

To Family, Friends, and my Academic Community

This dissertation would not have been possible without the enduring support of my advisor, Ph.D. committee, colleagues, family, and friends. First and foremost I want to acknowledge the unwavering support of my advisor and mentor, Dr. Tom Yeh, and my Ph.D. committee members. To Tom, you have created a platform from which I could explore; your steadfast belief and encouragement has enabled me to find my voice and use it powerfully. To Dr. Bridget Dalton, you have given me permission to be in full expression. To Dr. Clayton Lewis, you have shown me how to celebrate my accomplishments and have inspired me to strive for even greater impact. To Dr. Shaun Kane, you have consistently helped me make sense of the messiness and opened up new doors of inquiry. To Dr. Ben Shapiro, you have reminded me to stay true to my internal compass. To Dr. Ting Siu, you have taught me the power of acceptance and advocacy.

Along with my committee members, I have been fortunate to have received great support from my broader academic community. To Jill Dupre and Ruscha Cohen, your pragmatic love and existentialist knowing and truths have guided me through this process. Laura Nash, through your writing support I have learned the power of the word and the joy of the comma. To Dr. Allan Comp, Dr. Kevin Jansen, and Dr. Ajume Wingo your belief in my abilities opened up the possibility of pursuing a Ph.D. To Dr. Lisa Corwin, Dr. Jed Brubaker, Dr. Beth Osnes, Dr. Danna Gurari, and Dr. Leysia Palen, and Beth Stade, through your mentorship and camaraderie I have been able to find and stay true to my path. I also want to acknowledge my PhD colleagues and collaborators Dr. Halley Profita, Dr. Hyunjoo Oh, Dr. Louanne Boyd, Cindy Bennett, Jeeeun Kim, Ryo Suzuk, Khalid Alharbi, Melissa Bica, Dr. Marina Kogan,

Brittany Ann Kos, Simone Hyater-Adams, Donna Aguste, Lila Finch, Annie Kelly, David Oonk, for your vision and tireless efforts to alleviate social and environmental injustices.

My four parents and siblings have shown me the deepest form of love and have always encouraged me to explore and push boundaries with an open heart and brave soul. Mom, you always bring me back to my center. Dad, you opened the doors of creativity and making for me and have been my constant teacher. Terry, you have always supported my learning and keep me present in the moment. Arv, you are my comrade in finding truth and possibility. To my siblings (Tait, Grace, Alex, and Eden), you are my constant witnesses and support me through your attentive observation and love.

Along with my supportive family, I have been blessed with a chosen family. To my chosen sisters and brothers (Abby Bullock, Chris Carruth, Halley Profita, Heidi Crespi, Hyunjoo Oh, Janet Hollingsworth, Jenny Becksted, Karim Dimechkie, Lucy Burns, Mara Tegethoff, Markia Meertens, McClees Stephens, Odette Scott, Mustafa Naseem, Neil DiMuccio, Saskia Westof, and Vahid Mazdeh) you have ensured my sense of belonging in what could have otherwise been a lonely process. Regardless of the distance and time that keeps our lives moving in different directions, I am forever thankful to Foad for your constant belief in me, camaraderie, and heart.

Participation in the Tactile Picture Book Community

Just as my family, friends, and academic community have supported me, the research that I present in this dissertation has been greatly informed and supported through the people involved with the Tactile Picture Book Project, which, in 2016, morphed into the Build a Better Book Project. Dr. Yeh envisioned the Tactile Picture Book Project as a way to “formulate an approach to creating tactile pictures that (1) support young blind children’s emergent literacy

development, (2) are adapted to meet a child's specific needs, and (3) can be modeled and printed by commodity software and 3D printers." Inspired by Dr. Yeh's vision and dedication developing technical interventions that promote inclusion and equity, my graduate colleague Jeeeun Kim and I began our investigations into the design of tactile pictures for people who are BVI and material and technical platforms to support this task (Kim, Oh, & Yeh, 2015; Kim, Stangl, & Yeh, 2014; Kim & Yeh, 2015).

Though Dr. Yeh's encouragement and unwavering support, and Kim's camaraderie, I began investigating how to engage a broader audience in the design of tactile media. Dr. Stacey Forseth and Dr. Kathryn Penzkover, from CU Science Discovery[1], immediately saw the task of designing tactile media as a vehicle for engaging students in Science Engineering Technology and Math programming. Simotaneously, Dr. Bridget Dalton, an Associate Professor of Education (Curriculum and Instruction: Literacy Studies), saw the task of designing tactile media as a way to support students' multimodal literacy practices. Together Dr. Yeh, Dr. Forseth, Dr. Dalton, and Dr. Penzkover and I wrote a successful National Science Foundation, Innovative Technology Experiences for Teachers and Students grant (NSF #1615247) to form the Build a Better Book Project (BBB)[2]. Guided by Dr. Forseth's and Dr. Penzkover's determination and connection with the broader community, this project has become more than we first imagined. The opportunity to collaborate with Dr. Yeh, Dr. Forseth, Dr. Dalton, and Dr. Penzkover, the other graduate students—Ben Walsh and Kirsten Musetti—and our library and museum community partners

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[1] An engineering and math (STEM) education outreach program at the University of Colorado Boulder. Science Discovery manages programs that engage K-12 students and teachers in STEM and connect public audiences with the STEM research happening here at CU Boulder ("CU Science Discovery," n.d.).

[2] The Build a Better Book project "works with school and library Makerspaces to engage youth in the design and fabrication of inclusive media, including picture books, games and graphics. Using both low- and high-tech Makerspace tools, such as 3D printers, laser cutters, Makey Makeys, conductive boards and craft materials, youth design, fabricate, test and refine multi-modal books, games and STEM graphics that incorporate tactile and audio features. These products are designed by and for learners with visual impairments as well as other physical and learning disabilities("Build a Better Book," n.d.)."

(e.g. Janet Hollingsworth and Emily Zinn) on the BBB project has been a truly humbling experience.

My Role as a Participant Observer in Research

I have conducted much of the research presented in this dissertation as a participant observer[3]. I am greatly honored and indebted to the people who have opened up their homes, classrooms, and lives (in general) to me. In particular, I want to acknowledge the Anchor Center for the Blind, The Colorado Center for the Blind, and the National Federation of the Blind for allowing me to research alongside their members, students and families. Each of these education and advocacy-focused organizations have an outstanding commitment to supporting people who are blind and visually impired (BVI)[4] to have lifelong success and live the lives they want.

The opportunity to conduct my research with the support of the teachers, students, alumni affiliated with these organizations, has been a huge asset to this research an to me personally. From the first time I was taught how to guide BVI students to touch tactile materials so that they have the agency at to explore without my immediate mediation, to the moments when Julie Deden—the director of the Colorado Center for the Blind—politely informed me that it is ok to say "blind people" if that is how a person identifies, to the moment I was invited to serve on the NFB's Tactile Art and Graphics Steering Committee, I have become more aware and sensitive to the nuances of the human experience.

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[3] This methodology allows for studying processes, relationships among people and events, the organization of people and events, continuities over time, and patterns, as well as the immediate sociocultural contexts in which human existence unfolds (Scott & Kosslyn, 2015).

[4] Throughout this paper I write "about" people who are BVI. My hope is that I am accurately portraying their experiences and perspectives in a way that is true to how they have experienced them. To do this, I have made efforts to show my work to the people I have conducted this research alongside, as well as use people first language when it makes grammatical sense throughout this dissertation. I also rely heavily on direct quotes, rather than revoicing of people's views.

I also want to acknowledge that my view of people who are BVI has dramatically changed throughout the course of this research. While I was nervous in the beginning about how to interact around people who are BVI, I now recognize that regardless of a person's vision, they are people first. Jenny Callahan and Luanne Burke, once research participants and now dear friends, have perhaps been my greatest teachers in this respect.

A Leader in Tactile Arts and Education

I would like to especially acknowledge tactile artist Ann Cunningham (http://acunningham.com/), a community partner who has played an integral role in the BBB project, significantly influenced the work presented in Chapters 4 and 5, and profoundly influenced me as a tactile design researcher and person. I first met Cunningham in 2013 when she welcomed me to her studio to discuss her tactile art practice. Since that first meeting, I have observed her tireless commitment to create opportunities for inclusive media consumption, creation, and production. She has been working on creating and teaching others to create tactile art since 1992 when she first contributed tactile art, By Touch Alone, to an exhibit at Naropa University in Boulder, Colorado. In 1999 she started teaching tactile art at the Colorado Center for the Blind. I asked Cunningham to write a statement to attribute her contribution and our collaboration. In reflecting upon her original motivation for pursuing tactile art, she wrote:

> "With the advantage of hindsight, I can see there were many times throughout my life that my understanding of art, dyslexia, blindness, and touch collided and then spun off in a new direction. But it was one day in the early 1990s that all coalesced in a single moment, and I knew that I wanted to pursue tactile art. That was the beginning of a journey that I am still on. First, I needed to figure out what I meant by tactile art. I looked for others who were also doing similar work. There was not a great deal being done, but I

did find three key sources. I was able to find a book, Drawing and the Blind by John M. Kennedy, a perception psychologist, interested in how people who are blind can learn to interpret raised-line images as well as how untrained people who are born blind create their own pictures. I also found a museum program in New York City called Art Beyond Sight that was interested in making tactile representations of artwork accessible to people who are blind. And I stumbled upon the Tactile Gallery at the Colorado Springs Fine Arts Center which had recently opened in a nook of the museum."

Cunningham then explained how she started teaching art at the Colorado Center for the Blind (CCB):

"My desire to study the field was quickly overtaken with impatience, I felt like the greatest need was to get accessible images into people's hands, and from that, we would learn the most about what was possible and desirable. I turned to public art commissions as the best way to make this connection for my work and at the same time, I recognized the importance of working closely with people, who are blind, on making art techniques accessible as well. It was extremely fortunate that I was introduced to the Colorado Center for the Blind early in my search. In 1999 I began teaching art. Our art program continues to expand to this day. Even though we have just scratched the surface, there is actually a lot of knowledge that we have accumulated as an institution. It has become important to me and the Colorado Center for the Blind that the program survives me."

Cunningham recounted how we met, the level of mutualism between our goals for investigating to create a culture of inclusive tactile media creation, design, and production:

"About the same time I had that revelation, I also met Abigale Stangl. Perhaps it was even because of her that I started thinking about how can all this information be shared. I

feel fortunate to have met Abigale I can already see that our collaboration has resulted in an explosion of documentation around events and activities that are truly going to make a difference to people interested in the field. But more importantly, I feel that Abigale's critical examination of what is going on has sparked more interest in what we are doing and opened the door for many more people to find their way into and participate in this adventure."

Finally, Cunningham offers her vision for a future where accessible tactile media become abundant and common for blind children:

"We are seeing evidence that our efforts are falling on fertile ground. I hear about new tactile exhibits almost monthly. The National Federation of the Blind (NFB) is hosting the forth Tactile Arts and Graphics Symposium in the fall of 2018. We have a new art teacher who is visually impaired, Jenny Callahan, at the Colorado Center for the Blind. Our Drop-in Art Room at the NFB National Convention is expanding to host a community project led by Jenny. We are also initiating an artist to artist exhibition/conversation in advance of the public art reception for this year's art exhibition. American Action Fund is publishing an original tactically illustrated children's picture book. A collaborator, Matt Gesualdi is working with Meow Wolf on an exhibition for their new Denver location which will be a multi-sensory art experience. And I am working on three books that I would like to publish over the next two years. I have also been working with the Woodson Art Museum in Wausau, Wisconsin on a new tactile gallery. The NFB continues to promote tactile literacy to their youth studying STEM programs by including the extensive use of tactile images in their lessons and instruction in drafting. I am looking forward to the day when I meet a child, who is blind, who

cannot imagine a world without pictures. I think that day is closer than ever because of our growing community."

Ann Cunningham (June 27, 2018)

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CHAPTER 1:

INTRODUCTION

Problem Statement

Tactile media are the intervening substance through which impressions are conveyed through the sense of touch[5]. In another phrasing, tactile media may be defined as non-textual information created (crafted, designed, and/or produced) to be accessed through the haptic perception system to support access to information and experience through the sense of touch. Tactile media are part of an interconnected suite of access technologies that are integral for people who are blind and visually impaired (BVI) to become self-determined and literate (Kelly, 2012). Along with audio descriptions, they can make visual content and experiences accessible.

Tactile media can be intentionally designed to tactilely convey graphical representations of data or space (tactile graphics, diagrams, or maps) and other existing visual materials (pictures, illustrations, paintings, video scenes, games, computer screens, etc.). They can also be created (crafted, designed, and/or produced) and guided by the sense of touch—without visual references or metaphors to guide the communication of information, concepts, or experiences. Tactile media can have different compositional attributes: they can occur in the form of 2.25-dimensional (2.25D) raised line drawings (which are sometimes filled), 2.5-dimensional (2.5D) bas-relief sculptures, and/or 3-dimensional (3D) sculptures **(Figure 1.1).**

There are many different ways to produce tactile graphics. Conventional tactile production media include hand craft methods, such as hand drawn raised line drawings, collages

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[5] This definition is an adaption of the Oxford Dictionary's definition of medium (the singular form of media).

or bas-relief sculptures that can be reproduced through vacuum-formed (thermoform) plastics. These methods demand elaborate manual production of a physical master or template, which can be produced from different materials. Three-dimensional (3D) printing technology is an alternative to hand crafting, that allows for reproducing and adapting a digital model by producing a real tangible object from thermoformable filament **(Figure 1.1)**

Figure 1.1. Tactile Media Examples. (Left) Miffy the Rabbit: This tactile image contains a picture of a bunny holding a balloon. The text is in uncontracted braille and states that the image was created with TactileView software, Source: ("Perkins School for the Blind," n.d.); (Middle) Rabbit Tactile Graphic, Sources: ("Sensational Books," n.d.); (Right) Easter Rabbit Scan, Source (Thingiverse.com, n.d.)

Importantly, the circumstances in which a person teaches with or learns from a tactile composition can greatly change the way the media are understood. For example, a tactile illustration of a dog created as an act of personal expression will be considered tactile art. If the same tactile composition is picked up by a teacher of the visually impaired (TVI) and used to teach a student who is blind about a dog's anatomy, it may be considered as a graphic.

Despite the importance of these materials, our understanding of what leads to the use and design of effective media for people who are BVI is still nascent. While we have seen work coming from the field of perceptual psychology for decades investigating how people who are BVI read tactile graphics (Heller, Calcaterra, Burson, & Tyler, 1996; Heller, 1989; Morton A. Heller et al., 2006; Lederman, Klatzky, Chataway, & Summers, 1990; Morash, Connell Pensky,

Alfaro, & McKerracher, 2012), there are still many unanswered questions about haptic perception (the combination of tactile, proprioceptive, and kinesthetic information) and the formation of mental representations. Morash et al., 2012 specifies that the areas of questions center on 1) the spatial abilities of people who are BVI; 2) spatial development in BVI children; and 3) blindness and depth perception in two-dimensional depictions (Morash et al., 2012).

Only recently have we started to see peer-reviewed research articles from the vision sciences and education community examining how students who are BVI engage with tactile graphics produced in 2.25, 2.5, and 3D, e.g. (Beal & Rosenblum, 2018; Holloway, Marriott, & Butler, 2018; Mazella, Albaret, & Picard, 2016; Nashleanas, 2018; Rosenblum, Cheng, & Beal, 2018; Zebehazy & Wilton, 2014). Some of these studies are based on the accounts of teachers of the visually impaired (TVI)[6] regarding their students' tactile graphics usage, and all of the studies have low participation numbers and focus on tactile graphics. Few of these studies focus on the consumption and/or production of tactile pictures. Thus, my dissertation addresses this gap by contributing a study focused on describing N=46[7] community stakeholders' tactile picture design practices (Chapter 3) and a study focused on illuminating the issues and factors that impact tactile media consumption and production, as shared by N=84 BVI and sighted participants (Chapter 4).

While there are a handful of studies focused on how to instruct with tactile graphics (Rosenblum et al., 2018; Rosenblum & Herzberg, 2015; Steele, 2015), the body of work on

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[6] Teacher of Students with Visual Impairments (also called a Teacher of the Visually Impaired, a vision specialist, VI teacher, vision itinerant teacher, etc.) Such a person is typically a licensed special education teacher who has received certification and specialized training, in meeting the educational needs of students who are blind or have visual impairments ages birth through 21 (states vary on the criteria for certification as a Teacher of Students with Visual Impairments). This is an instructional position, as opposed to a related service or vision therapy("Teacher of Students with Visual Impairments," n.d.).

[7] Children librarians (n=6), a group of accessible media librarians, (n=6), a group of engineers with interest in supporting people with VI (n=3), a group of interaction designers interested in supporting people with VI (n=4), a group of volunteers who work at an accessible media library (n=7), and a group of TVIs and orientation and mobility (O&M) specialists (n=40).

tactile graphics is nascent and tend to focus on mathematical diagrams alone. Fewer still are peer-reviewed studies on how people—sighted or BVI—engage in the design of tactile media; it was only in 2010 that the first tactile graphics standards and guidelines emerged, e.g. the Braille Authority of North America, Guidelines and Standards for Tactile Graphics (Braille Authority of North America, 2010).

There are several reasons for the scarcity of scholarship on tactile media for people who are BVI. First, in Western culture, touch and tactility have historically been passed over in many fields since vision is regarded as the "noblest of the senses" (Pallasmaa, 2012, p. 15). To this point, Jehoel et al. (2006) state that research in psychology (perceptual and cognitive) is predominantly centered on visual and auditory information processing, not tactile perception and cognition for teaching and learning (Jehoel, McCallum, Rowell, & Ungar, 2006).

Another explanation for the scarcity of research on ways in which the "low-incidence nature of visual disabilities" (Ferrell, Mason, Young, & Cooney, 2006). The prevalence and incidence of visual impairment in people of age 20-59 years in industrialized countries is approximately 0.08% (Rothe Nissen, Sjølie, Jensen, Borch-Johnsen, & Rosenberg, 2003). The low-incidence of visual disabilities has limited the funding for research involving students with visual impairments (Corn & Ferrell, 2000; Hatton, 2014; Mason & Davidson, 2000), the number of training programs for vision specialists (who have a central role in creating tactile media for their students) (Bozeman, Brusegaard, & McCulley, 2018), as well as the research designs that can be utilized when conducting research with people who are blind or visually impaired (Ferrell et al., 2006, p. 4).

The low-incidence nature of visual impairment, in addition to the well-documented discrimination of people with disabilities (Fine & Asch, 1988), has perhaps also impacted the

timeliness of governmental legislation to support educators, students, and other tactile media creators' access to and distribution of tactile media. While the United States has a long history of governmental efforts to support the development and distribution of accessible reading materials for general use and educational purposes [8], much less focus has been placed on the creation and distribution of tactile graphics, pictures, illustrations, and the accessibility of art.For example, it was only in October of 2018 that the United States copyright rules changed to permit reproduction and distribution of accessible published works that included tactile graphics[9].

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[8] The first efforts to make accessible reading materials available to the public occured in 1897, when John Russell Young, the Librarian of Congress, established a reading room for the blind with approximately 500 books and music items in raised characters. In 1931, the Pratt-Smoot Act passed to allocate $100,000 to the Library of Congress for providing blind adults with books and incited the establishment of the National Library Service for the Blind and Physically Handicapped (NLP)(Overview). Ten years later, in 1941, the United States government passed P.L. 77-270 amended P.L. 45-186--the first legal provision focused on equitable access to literary materials for the blind. This act purveyed Franking Privileges for people who are blind and free circulation of reading matter for people who are blind, including braille writers and other appliances when mailed for repair. In 1968, P.L. 91-61 was passed to establish the National Center on Educational Media and Materials for the Handicapped. In 1974, Congress increased the appropriation to the Library of Congress for the fiscal year 1974 to provide for two centers serving multistate areas as decentralized storage and distribution points for braille materials and talking books.

Efforts to support the development and distribution of accessible tactile reading materials for primary and secondary educational purposes began in 1879 the Congress of the United States passed the Act to Promote the Education of the Blind. This act established a permanent annual appropriation for the specific purpose of "manufacturing and furnishing books and other materials specially adapted for instruction" of students who are blind in the United States and its Territories. Since that time, the American Printing House was designated as the official supplier of educational materials to all students in the U.S. who meet the definition of blindness and are working at less than college level(American Printing House for the Blind, n.d.).

[9] In 1996, for the first time, U.S.-based copyright law accounted for the restrictions that impacted the creation and distribution of accessible material. The "Chafee Amendment" (Section 121 of the US Copyright Act), signed in 1996, stated that it is not an infringement of copyright for an authorized entity to reproduce or to distribute copies or phonorecords of a previously published, nondramatic literary work if such copies or phonorecords are reproduced or distributed in specialized formats exclusively for use by blind or other persons with disabilities ("17 U.S. Code § 121 - Limitations on exclusive rights: Reproduction for blind or other people with disabilities," n.d.)." Prior to passage of Chafee, any distribution of copyrighted material in specialized formats to people with disabilities could only be done after receiving explicit permission from the copyright holder. While the Chafee act enabled organizations such as the American Printing House and other non-profit braille publishers such as the National Braille Press to transcribe textbooks and create other accessible learning materials, the national Copyright law prohibited the distribution of such materials to other countries. Accordingly, in 2013 the World Intellectual Property Organization signed the Marrakesh Treaty with a number to create the first set of standard limitations and exceptions to copyright rules in order to permit reproduction, distribution and making available of published works in formats designed to be accessible to Visually Impaired Persons, and to permit exchange of these works across borders by organizations that serve those beneficiaries. The countries which ratify the treaty must ensure their laws allow blind people and their to make accessible format books without the need to ask permission first from the holder of copyright (e.g. author or publisher)(World Intellectual Property Organization, n.d.)". In the United States, the Marrakesh Treaty was not put into effect until October 2018. The current version of the Treaty mandates several key amendments to Section 121 of the Copyright Act, including 1) an expansion of the types of works allowed to be

The scarcity of the literature focused on BVI people's use of tactile graphics, TVIs instruction with tactile graphics, and the design of tactile media for and by people who are BVI, as well as the general dearth of tactile media, presents a formidable challenge for people invested in finding, using, creating, and teaching with tactile media. In fact, there are few formalized instructional resources to train TVIs and rehabilitation specialists to teach with tactile media and to engage in the design of different forms of tactile media. One of few existing resources that focuses on supporting teachers in identifying their students' tactile learning needs is the Learning Media Assessment (LMA), a tool used to evaluate the efficiency with which the K-12 student gathers information from various sensory channels, the types of general learning media that the student uses, or will use, during reading and writing (Koenig, J. Holbrook, C. 1995). The LMA is a resource that helps a teacher assess their student's learning style or the way in which he or she uses vision, touch, hearing, and other senses, either singularly or in combination, to gain access to information. The assessment is primarily used to identify the appropriate teaching method between print and Braille—but does not focus on tactile media's use or creation.

Importantly, perceptual psychologist Frances Aldrich wrote the "Agenda for Further Research on Tactile Graphics" in 2008 to "orient mainstream researchers to the principal challenges in the field of tactile graphics" (Aldrich, 2008, p. 345). She posed the overarching question, "How can tactile graphics be designed and used as effective representations [for people who are blind or visually impaired]?" In this agenda, she also asked three additional questions to provoke future research: (a) "Tactile graphics are usually simplifications of visual graphics. What would they be like if we designed them from scratch?" [as opposed to designing the media

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copied from nondramatic literary works to all literary works, plus musical works fixed in the form of text or notation; 2) **Changes the term "specialized formats," "accessible formats," defined as alternative manner or format, and extends this definition to illustrations**; and 3) Updates how the definition of the beneficiaries of section 121, which were originally termed "blind or other persons with disabilities," to "eligible person (World Intellectual Property Organization, n.d.).

from an existing visual reference]"; (b) "Is it 'right' to consider graphical representations to be essentially visual?," and (c) "What concepts surrounding tactile graphics or materials should be introduced to teachers (given that many educators are provided little guidance)?"

While Aldrich's questions represent important lines of inquiry regarding the design of and instruction of tactile graphics, her questions center on tactile graphics as opposed to the creation of other formats of tactile materials—pictures, illustrations, sculptures, multimodal compositions—as well as how, when, and why people consume tactile materials. A comprehensive overview of people's tactile media practices is still needed to introduce and guide contemporary and future practitioners and scholars who are interested in on advancing the field of tactile media studies for people who are BVI. Chapter 4 of my dissertation provides such an overview by identifying the core problems of practice impacting the consumption and production of tactile media for people who are BVI. I draw on these findings to suggest the design of a "Curriculum for Inclusive Media Creation, Design and Production" (Chapter 5).

During my efforts to develop opportunities for BVI and other sighted individuals in the creation of tactile art and graphics[10], as well as in my efforts to conduct empirical research on these topics, I identified the need for a comprehensive overview of people's tactile media practices while designing tactile media myself. I have traversed in and out of early intervention classrooms, rehabilitation and independence training centers, design studios, research laboratories, and community meetings. I have been in pursuit of a comprehensive guide for how to conduct robust research that will increase BVI people's access to tactile media—in school, at home, in museums, and other public institutions—and position more BVI and sighted parents, caregivers, and other invested stakeholders to be tactile media designers and improve the

[10] The Build a Better Book Project. I am a key member of this project. We work with school and library Makerspaces to engage youth in the design and fabrication of inclusive media, including picture books, games and graphics.

accessibility of our presumptive information systems. As media theorist Deuze (2011) notes, consumption of media only constitutes half of media life—or a state where media is seen as intrinsically part of life, not outside of it (Deuze, 2011). Creation, design, and production constitute the other half and are increasingly being recognized as critical practices in a person's literacy development (which includes print literacy, multimodal, maker, and media and information literacies (Talja, Tuominen, & Savolainen, 2005).

I have found that much common knowledge about tactile media consumption, creation, and instruction is held by the students and practitioners who engage in the teaching with, learning with, and creation of tactile media on a daily basis. Much of this knowledge and experience has not been documented or empirically investigated. These issues are only compounded by the fact that many people who are BVI do not find useful information, nor do parents and practitioners who have the most direct interactions with students who are BVI. Ergo, the overarching problem statement that guides this research is: There is a lack of empirically gathered and documented evidence about how people—BVI and sighted—effectively engage in tactile media practices to support their own and other people's participation in education, civic life, and professional and personal endeavors. My thesis is designed to address this gap, focusing on the overarching goal of raising awareness of the factors that impact full inclusion[11] of people who are BVI in the media and information landscape. This is accomplished through three studies

[11] We know that inclusion of people in activities that directly impact their lives is a first step towards creating equity. For example, the inclusive education movement that led to educational policy reform in 1975 titled the Education for All Children Act (also known as Public Law 94-142) ("S. 6 (94th): Education For All Handicapped Children Act," n.d.) greatly impacted many people's' lives. PL 94-142 mandates that all children and youth, regardless of their differences in culture, gender, language, ability, class, and ethnicity are provided equal education. It also contains a provision that disabled students should be placed in the least restrictive environment-one that allows the maximum possible opportunity to interact with other students.

that, taken together, show we need new approaches to ensuring that people who are BVI are positioned to in[12] tactile media consumption, production, and instruction.

Motivation

As an interdisciplinary scholar conducting this research at the intersection of HCI and access technology design, design studies, and education research, I approached this research by conducting human-centered research to inform the design of new multisensory experiences through new and innovative technologies. This search brought me into the field of HCI and Access Computing and enticed me to pursue a Ph.D. with Dr. Tom Yeh and the Sikuli Lab after my masters work in Information Communication Technology for Development, and my bachelor's studies in Environmental Design and Social and Environmental Justice.

Early on in my Ph.D investigation, I read that the creation of tactile media for and with people who are BVI is a task guided by "the objective to maintain an exchange of meaning between the people who are sighted and people who are BVI (Darras & Valente, 2010, p. 4)". This perspective of tactile media design draws on Peirce's theory of pragmatic semiotics, and the notion that such an exchange of meaning occurs "within interpretative communities that regulate common sense and diverse experiences (Darras & Valente, 2010, p. 7)." Darras and Valente also inferred two design principles: 1) Meaning is made in the context [social construction] through which tactile media are experienced by the user, as opposed to meaning being made through the internal organization of a system of signs; and 2) Transposition of image into tactile media involves the ability to engage in meta-representation of one's and others' mental state. I was intrigued by the idea that tactile media are a social resource that can bring people together to

[12] Through media means the ways in which media becomes a mediator of participation in public debate and self-representation in physical and digital public spaces (Carpentier, 2011). While we already know that people with disabilities--including people who are BVI--are not equitably portrayed or represented in the mediascape e.g., (Ellis & Goggin, 2015), we do not yet know is how to support people who are BVI through media.

form a shared understanding of a concept (if and when a person has access to them and they contain accessible representations), and that without such media some concepts may not otherwise be accessible to a person who are BVI. Furthermore, as a designer I was interested to see if I could create an artifact that would open up new understanding for another person.

Furthermore, while the development of technical systems that make graphical information more accessible for people who are BVI has been a focus of mechanical engineers, electrical engineers, and computer scientists since the 1970's (Bliss, Katcher, Rogers, & Shepard, 1970), I believe that that the design and development of these systems will greatly benefit from more empirical investigations into the tactile media practices of people who are BVI and the people who are directly involved with ensuring the accessibility of tactile media, access to all forms of media, and full inclusion and participation in the creation of all forms of media.

Study Overview

With this mission in mind, and as a step towards addressing the aforementioned problems, I present three interventionist studies designed and implemented to investigate the practices of people engaged in finding, using, creating (crafting, designing, and producing), and/or instructing with tactile media. Tactile media are important learning resources for people who are BVI to develop an understanding of non-verbal, visual, graphical or pictorial information and other physical materials and experiences through the sense of touch. In the case of this research, I am not referring to Braille or other forms of accessible text as tactile media. Braille is a tactile writing system used by people who are BVI[13]. While Braille is an incredibly important form of tactile text, and the skills to read and write Braille are most certainly involved

[13] Braille users can read paper embossed with Braille characters or computer screens and other electronic supports using refreshable Braille displays. To write Braille, a person may use a slate and stylus or type it on a braille writer, such as a portable braille notetaker or computer that prints with a braille embosser.

in tactile media consumption and production, the study of how people engage in Braille reading and writing (Braille literacy) is an entire research field to itself.

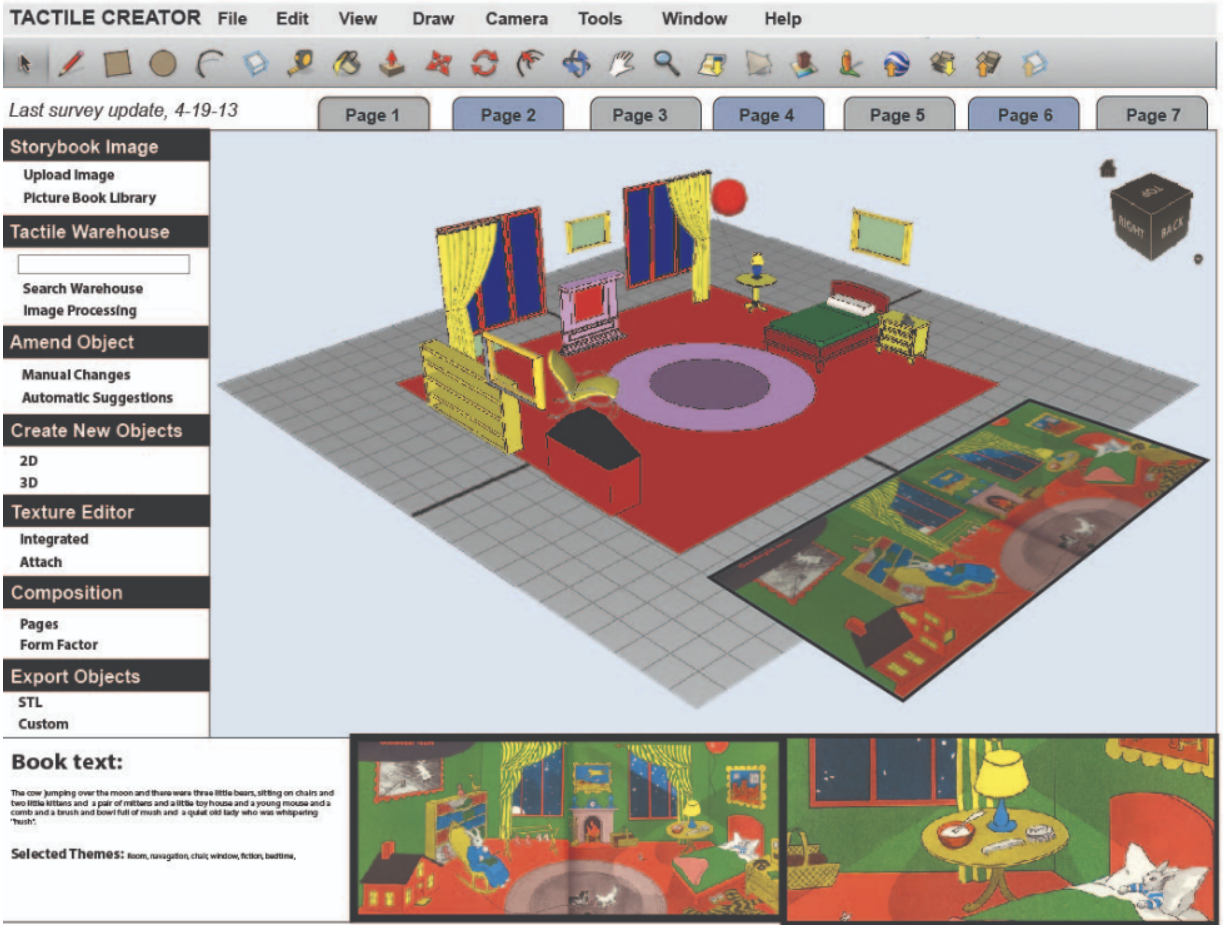

Figure 1.2. First Tactile Design Interface Sketch of illustrations from the well-known children's picture book, Goodnight Moon.

Interventionist Research

My understanding of the problem space began during the first semester of my Ph.D. as I worked in Dr. Yeh's Lab and attempted to transcribe visual illustrations into tactile representations and develop an interface to support this process (Figure 1.2). Through this process, I began to reflect on the end-users' experiences with graphic media and wondered about the broader social, technical, and sociotechnical issues that impact access to information and thus

information literacy for people who are BVI. Of note, Ratto (2011) refers to this kind of reflective practice as Critical Making, or "connect[ing] modes of engagement with the world that are often held separate—critical thinking, typically understood as conceptually and linguistically based, and physical "making," and goal-based material work (Ratto, 2011, p. 253)."

During these initial tactile media design investigations, I did not have any contact with people who BVI, or their caregivers, teachers, or other people involved in using, developing, or teaching with tactile materials, nor did I have a sense of my multimodal literacy needs and interests. Instead, I relied on the Braille Authority of North America, Guidelines and Standards for Tactile Graphics (Braille Authority of North America, 2010), my own prior experiences as an environmental designer, and my PhD advisor (Dr. Tom Yeh). However, as I became more familiar with the considerations that arise when designing tactile media. For instance, such media should not be created without the input of people who are blind and their caregivers and without attunement to how different modalities can be used to support meaning making. While in recent years multimodal literacy (New London Group, 1996) has become more accepted, and it it has become best practice to include the end-user in design and research processes either as participants or co-designers (Laitano, 2017), these methods are not always used in design and development processes.

I designed and implemented the three studies presented in this dissertation through direct engagement with people who are BVI, their caregivers and teachers, and other invested practitioners and scholars, including the Tactile Picture Book Project team at CU Boulder, now known as the Build a Better Book Project ("Build a Better Book," n.d.). This dissertation required me to work out the tension between the descriptive nature of anthropological research and future-making/ interventionist research, a process referred to as Research through Design

(RtD) (Zimmerman, Forlizzi, & Evenson, 2007)[14]. Mingers and Brocklesby (1997) provide an explanation of "intervention" that further clarifies the notion of future-making/interventionist research: intervention covers the scenarios in which evidence of a problem is present to an external agent (designer, design-researcher, etc.) who enters an unknown situation and leaves at the completion of the project. Interventions include "a set of actions" that enable researchers to analyze the underlying structure/constraints that give rise to the problem space, assess the ways in which the situation could be other than it is, and/or bring about desirable changes through direct actions (Mingers & Brocklesby, 1997, p. 492). Each of the studies I present is interventionist in nature and includes the analysis of qualitative data collected through activities where participants engaged in and discussed their tactile media consumption, production, and/or instruction practices. RtD and other interventionist research fall under the practice-based paradigm of research.

Practice-based research draws on the notion that knowledge and learning are not solely conceived as mental processes residing in single person's head; rather, they must be viewed as forms of social expertise that are informed by historical, social, and cultural contexts. While perceptual, cognitive, and neurological factors can surely affect how people engage in consumption, design/production, and instruction, it is not within the scope of this dissertation to explicitly investigate how and why these biological factors impact people's abilities to engage in such practices. Instead, the studies in my dissertation focus on the social and technical factors that affect people's tactile media consumption, design/production, and instructional practices.

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[14] RtD has ties to human-computer interaction (Zimmerman, Forlizzi, & Evenson, 2007), design anthropology (Smith et al., 2016), and design-based educational research, e.g. Design-Based Implementation Research i.e. (Penuel, Fishman, Haugan Cheng, & Sabelli, 2011) and Formative Interventions i.e. (Sannino, Engeström, & Lemos, 2016).

This approach aligns with the social model of disability, a term first coined by Mike Oliver (Oliver, 1983) in reference to the ideological developments shared in the Union of the Physically Impaired Against Segregation (UPIAS) in England in the 1970s: “In our view it is a society which disables physically impaired people. Disability is something imposed on top of our impairments by the way we are unnecessarily isolated and excluded from full participation in society” (UPIAS, 1976). The social model of disability examines the way society is organized and the impact of such organization on the person's or group’s opportunity to participate. By bringing attention to the ways in which disability is socially produced, the social model has succeeded in shifting debates about disability from biomedically dominated agendas to discourses about politics and citizenship. The social model of disability differs from the medical model of disability, which focuses on curing or managing illness or disability and places the cause of disability on the individual; as opposed to asking “why are people who are BVI not able to access information”, we ask what are the social and technical factors and issues that impede their access to tactile media? (Study 3, Research Question 1, **Table 1.1**).

While each of my studies has different specific research questions, all aim to address the overarching problem statement given above: There is a lack of empirically gathered and documented evidence about how people—BVI and sighted—effectively engage in tactile media practices to support their own and other people's participation in education, civic life, and professional and personal endeavors. This broad problem statement leads to general questions:

1. What considerations and/or practices do people who are BVI engage in when consuming tactile media, and specifically, tactile graphics and art?

2. What considerations and/or practices do sighted and BVI practitioners engage in when creating (making, designing, producing) tactile media, and specifically, tactile graphics and art?
3. What considerations and/or practices do sighted and BVI practitioners engage in and develop when teaching with tactile media, and specifically, tactile graphics and art?

These research questions are addressed to two distinct activities involved in any literacy practice—consuming and creating tactile media—and one overarching activity—instruction. I make these activities distinct in the exploration of the questions because I want to place equal emphasis on both the consumption and the production of tactile media by people who are BVI. In contrast, existing literature on the literacy practices of people who are BVI (and the professionals responsible for helping develop such practices) focus heavily on people's consumption.

As any researcher who conducts interventionist research might, I aim to provide recommendations or solutions to the factors that impact how people—BVI and sighted—effectively engage in tactile media practices to support their own and other people's participation in education civic life, and professional and personal endeavors. Thus, a fourth research question has guided the research presented in this dissertation:

4. What design strategies can be implemented to address the factors that limit BVI people's tactile media consumption, creation, and instruction practices?

Individual Study Questions and Methods

While the overarching approach to the research presented in this dissertation is Research through Design, as mentioned above, each study follows a unique procedure. In this section, I

present a summary of each study, the specific research questions, and a brief description of the research procedures (**Table 1.1).** Presents an overview of all of the research questions.

Table 1.1. Research Questions Across 3 Studies.			
	Study1	Study 2	Study 3
Chapter Title	Chapter 2: Teachers And Caregivers' Familiarity And Interest In Tactile Media For Children Who Are BVI: A Design Investigation.	Chapter 3: Transcribing Across The Senses: Community Efforts To Create 3D Printable Accessible Tactile Pictures For Young Children With Visual Impairments.	Chapter 4: Consuming And Producing Tactile Media: Contemporary Perspectives and Practices To Advance The Field of Tactile Media Studies
Research Question 1:	(1) What are parents' and teachers' familiarity with tactile pictures and learning media for children who are visually impaired?	(1) What distinct stakeholder groups are interested and willing to contribute to developing 3D printable accessible tactile picture (3DP-ATPs), and how/what do they contribute?	What are the factors/issues that impact the art and graphics consumption, production, and instruction, practices of participants who attended the Tactile Arts and Graphics Symposia (TAGS)?
Research Question 2:	(2) What are the characteristics of the media used to support children with visual impairments tactile learning and related design strategies?	(2) How do these groups differ and what do they have in common in terms of motivation, design approach, and skill?	What strategies do the TAGS participants identify as contributing to or inhibiting access and participation?
Research Question 3:	(3) What are parents' and teachers' interests in 3D printing as a means of creating tactile learning materials?	(3) How can distinct stakeholder groups' skills be leveraged to increase the supply of 3DP-ATP?	What do the factors/issues and strategies reveal about the problems of practice related to tactile media that the TAGS participants and in turn similar stakeholders encounter?

Study 1 (Chapter 2)

In Chapter 2, I present a study titled "Teachers And Caregivers' Familiarity And Interest In Tactile Media For Children Who Are BVI: A Design Investigation," which specifically focuses on understanding parents' and caregivers' familiarity with tactile pictures to support their BVI preschool students' emergent literacy, as well as their interest in 3D printing as a way to produce tactile pictures and support their acquisition of accessible pictures for their children. The content of this chapter was originally published as two short papers in the Extended Abstracts of the conference on Computer-Human Interaction (Stangl, Kim, & Yeh, 2014) and the Proceedings of the Interaction Design and Children Conference (Stangl, Kim, & Yeh, 2014). The research questions guiding this effort include:

1. What are parents' and teachers' familiarity with tactile pictures and learning media for children who are visually impaired?
2. What are the characteristics of the media used to support children with visual impairments tactile learning and related design strategies?
3. What are parents' and teachers' interests in 3D printing as a means of creating tactile learning materials?

To answer these questions, I led a user-centered design (UCD) effort through which I collected fieldnotes as a participant observer at an early intervention center for young children who are BVI over the course of 15 visits. I used affinity diagramming to identify the common themes that emerged from our observations (Beyer & Holtzblatt, 1998; Simonsen et al., 2014). My colleague Jeeeun Kim and I applied these findings to create a series of 3D printed tactile picture prototypes. Our final design became a design probe (Gaver, Boucher, Pennington, & Walker, 2004), which we used to solicit additional information about parents and teachers interest in 3D printing, and to identify design strategies that can be used in the creation of tactile pictures to

support children who are BVI engage in reading. Our deployment of the design probe solicited feedback from N=28 participants. (Chapter 2 provides an elaborated description of our procedures and findings).

Study 2 (Chapter 3)

In Chapter 3, I shift focus to investigate how teachers and other community stakeholders engage in the design of tactile pictures that can be 3D printed. This study is titled "Transcribing Across The Senses: Community Efforts To Create 3D Printable Accessible Tactile Pictures For Young Children With Visual Impairments." This study was originally published in the Proceedings of the Conference on Computers and Accessibility in 2015 (Stangl, Hsu, & Yeh, 2015). The research questions guiding this effort include:

1. What distinct stakeholder groups are interested and willing to contribute to developing 3D printable accessible tactile picture (3DP-ATPs), and how/what do they contribute?
2. How do these groups differ and what do they have in common in terms of motivation, design approach, and skill?
3. How can distinct stakeholder groups' skills be leveraged to increase the supply of 3D Printable-Accessible Tactile Pictures?

To answer these questions, I led the design and implementation of six, four-hour tactile picture design workshops with a total of N=66 sighted participants who were interested in designing tactile media for children who are BVI. The participants included children's librarians (n=6), a group of accessible media librarians, (n=6), a group of engineers with an interest in supporting people with VI (n=3), a group of interaction designers interested in supporting people with VI (n=4), a group of volunteers who work at an accessible media library (n=7), and a group of TVIs and orientation and mobility (O&M) specialists (n=40). My collaborators Hsu and Yeh and I

took field notes and audio recordings while implementing each workshop. To analyze this data, we wrote analytical memos that focused on participant concerns and considerations while approaching the design task and while engaging in 3D modeling. We ranked each participant and participant group and their dominant skill sets, and subsequently used this ranking system to analyze video from the workshop. Chapter 3 provides an elaborated description of our procedures and findings.

Study 3 (Chapter 4)

The findings and experience of designing and implementing the studies presented in Chapter 2 and 3 informed the design and implementation of the study presented in Chapter 4, titled "Consuming And Producing Tactile Media: Contemporary Perspectives and Practices To Advance The Field of Tactile Media Studies." In this study, I investigated the broader problems of practice that impact how people engage in finding, using, creating (crafting, designing, and producing), and/or instructing with tactile art and with tactile graphics. While this study has not yet been published, it draws in part from a report written for the NFB documenting the activities that occurred during three Tactile Arts and Graphics Symposia (TAGS). The research questions guiding this effort include:

1. What are the factors/issues that impact the art and graphics consumption, production, and instruction practices of participants who attended the Tactile Arts and Graphics Symposia (TAGS)?
2. What strategies do the TAGS participants identify as contributing to or inhibiting access and participation?
3. What do the factors/issues and strategies reveal about the problems of practice related to tactile media that the TAGS participants and in turn similar stakeholders encounter?

Chapter 5

In Chapter 5, Conclusion and Future Directions, I begin by providing a brief summary of the core findings from each of the three studies, including a description of the limitations of each study, and discuss how they help address my overarching research questions[15]. I then discuss the broader implications of this work and directions for future research. As part of my discussion for future work I propose three interrelated research agendas: 1) Increasing the Inclusion of BVI People in the Creation of Media; 2) Development of a Pedagogy for Inclusive Tactile Media Creation; and 3) Developing a Tactile Media Studies Community of Practice.

Statement of Contribution

These investigations present important insights about the lived experiences and practices of people engaged in finding, using, creating, and instructing with tactile media for people—BVI and sighted—who are immediately engaged in creating equity within teaching and learning, civic life, economic, and consumer life for and with people who are BVI. My experience of designing and implementing these studies revealed that finding, accessing, using and creating tactile media are common challenges facing anybody interested in supporting the tactile literacy abilities of people who are BVI, as well as BVI people themselves. Furthermore, throughout my studies, I have noted that many of the people engaged in tactile media practices (acquisition, use, creation, and instruction) have lacked forums where they can share and reflect on their tactile experiences with other people who are interested in tactile media, despite the fact that many people face the common challenges.

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[15] 1) What considerations and/or practices do people who are BVI impaired engage in when consuming tactile media? 2) What considerations and/or practices do sighted and BVI practitioners engage in and develop when creating (making, designing, producing) tactile media? 3) What considerations and/or practices do sighted and BVI practitioners engage in and develop when teaching with tactile media? And 4) What design strategies can be implemented to address the factors that limit BVI people's tactile media consumption, creation, and instruction practices?

Across these studies, I present a line of inquiry to advance our understanding and practices in tactile graphics and art for BVI individuals. In Chapter 2, I show that many parents and teachers struggle to find tactile pictures and books to read with their children, let alone have the time and resources to create them. In Chapter 3, I demonstrate that despite the existence of tactile media design guidelines for tactile graphics (Braille Authority of North America, 2010; Edman & American Foundation for the Blind, 1992; Schuffelen, 2002; TAEVIS, 2002), and tactile pictures or illustrations (Claudet, 2014; Claudet & Richard, 2009; "Guide to Designing Tactile Illustrations for Children's Books," 2009), many community stakeholders who are interested in learning to design tactile pictures and graphics do not know about these resources or know how to apply them to their design work. Also in Chapter 3, I present evidence that community-designers often have something unique to contribute to the task of designing tactile media yet do not have a forum to share and exchange their knowledge and experience. In Chapter 4, I share new knowledge I gleaned from the stakeholders who are invested in tactile media consumption, production, and instruction, with an emphasis on learning from BVI individuals. I present my analysis of the inputs provided by these stakeholders in Tactile Arts and Graphics Symposia (TAGS) regarding the factors affecting the access to and the accessibility of tactile media for people who are BVI.

CHAPTER 2:

TEACHERS' AND CAREGIVERS' FAMILIARITY AND INTEREST IN TACTILE MEDIA FOR CHILDREN WHO ARE BVI: A DESIGN INVESTIGATION

Prelude

The research presented in this Chapter began in 2012 with the speculation that 3D printing could be used to design and produce tactile pictures for children who are Blind and Visually Impaired (BVI). As a design researcher who was not yet familiar with the learning needs of children who are BVI, the nuances of tactile picture design, or 3D printing, I embarked on what would become a multi-staged Research through Design effort aimed at understanding the context in which tactile pictures for emergent literacy are used. While this research was first motivated by the vision that 3D printers will make tactile pictures more available to parents, teachers, and other invested stakeholders, I understood that the application of 3D printing would only be relevant if it met the real-life needs of people engaged in reading with children. I was particularly interested in how parents and teachers of the visually impaired (TVIs) engage their young children in co-reading experiences and their familiarity with tactile pictures generally. Furthermore, I was interested in whether parents and teachers were aware of 3D printing as a potential production method that could increase their access to important teaching and learning media.

In this chapter, I present my effort to answer these questions. My investigation occured between 2013 and 2014 in collaboration with Jeeeun Kim and Dr. Tom Yeh; the work was initially published as two short studies in 2014. The publication of the first study, titled

"Technology to Support Emergent Literacy Skills in Young Children with Visual Impairments" appeared in the Extended Abstracts of the conference on Computer-Human Interaction (Stangl, Kim, & Yeh, 2014). The findings presented in this paper concentrated on the participant-observations described in this chapter. The second study, "3D Printed Tactile Picture Books for Children with Visual Impairments: A Design Probe" (Stangl, Kim, & Yeh, 2014) appeared in the Proceedings of the Interaction Design and Children Conference. The findings presented in this paper centered on the creation of a 3D printed tactile picture design probe[16].

This chapter serves two purposes. First, it sets the stage for the two subsequent papers in the dissertation; one common theme throughout each chapter is my commitment to working with end-users to gain an understanding of the contexts in which technology (in this case 3D printed tactile pictures) will be used. Second, the efforts presented in this chapter were some of the first studies published on the employment of 3D printing to create tactile pictures—as opposed to tactile graphics which are typically developed for older students.

Abstract

Developing emergent literacy skills and attitudes within children with visual impairments is critical to cultivating their lifelong ability to construct concepts about the function of symbols and develop tactile acuity. In this paper, we present a Research through Design effort which revealed insight into parents' and teachers' familiarity with tactile pictures and their experiences and interest in 3D printing as a possible production technology. We obtained this insight while

[16] Merging of these two short papers into one long paper required a substantial reorganization of the content; both of the original short papers lacked a clear background, methods, findings, and discussions sections. Rather, they focused on identifying the need space and possible solutions, whilst glossing over important procedural procedural details. I reorganized the text so that it would reads as one comprehensive research effort--which it was--without changing the tone or the content of the text to a large extent. The downside of merging these papers is that the methods gaps become more apparent. Namely, at this early stage of research I did not capture detailed demographic data for the people I was observing, or the respondents of the Design Probe we deployed.

conducting qualitative observations in an early intervention school for toddlers who are blind, and while designing and deploying a 3D printed design probe. The 3D printed design probe enabled us to reach stakeholders outside of the early intervention center, thus gaining further insight into 1) the technical and human processes required to create 3D printed tactile pictures, and 2) whether 3D printing is an appropriate production method for creating emergent literacy-focused materials.

Introduction

Emergent literacy—the ability to construct concepts about the functions of symbols and print—starts to develop in people just after birth through experiences and meaningful language exchanges facilitated with adults (Stratton, 1996). Co-reading experiences enable parents and children to make emotional bonds and relate to one another about their surrounding environments, objects, and relationships, as well as to expand creativity and vocabulary and to instigate new conversations. Furthermore, these interactions inform parents about their child's learning needs, styles, and progression into literacy. For children who are born with or who acquire visual impairments (BVI), co-reading is particularly important to help a child develop tactile acuity and mobility, their sense of seeing or feeling of their environment, as well as their confidence to explore and build relationships and associations through touch.

Illustrated picture books typically provide a medium through which parents and their children can engage in the co-reading experience. However, many of these visually oriented picture books are not accessible to children who are BVI. In turn, families with children who are BVI may acquire children's books that contain an additional layer of tactile information. Despite this need, there is an insufficient selection of tactile picture books that are available for purchase for a variety of reasons, including the cost of production.

In this paper, we present a user-centered design (UCD) research effort that was motivated by the vision that 3D printers will make tactile pictures more available to parents, teachers, and other invested stakeholders. Based on our initial investigations, we engaged in the design and distribution of a 3D printed design probe (Gaver, Boucher, Pennington, & Walker, 2004) to solicit additional information about parents' and teachers' interest in 3D printing, and to identify design strategies that can be used in the creation of tactile pictures to support children who are BVI engage in reading. The findings and discussion we present emphasize the importance of understanding how children who are BVI are supported to develop emergent literacy. We also identify socio-technical design opportunities that leverage the advantages of 3D printing yet take into consideration the needs of parents and teachers.

Background and Related Work

Tactile picture books often cost much more than illustrated picture books for children. For example, a version of the book, "Goodnight Moon" by Margaret Brown in tactile format costs approximately $30 for the consumer. Due to the cost of producing tactile picture books, publishers like American Printing House for the Blind (APH), National Braille Press (NBP), and Seedlings are only able to develop a few projects per year. The NBP, for example, only carries nine copies of "Goodnight Moon". In 2013, a representative from the APH noted, "As purchase quantities drop, items become more expensive and in some instances, items cannot be purchased at any price in lower quantities." To mass-produce these books, publishers must hire tactile artists to create a master and then refine that master into efficiently reproducible tactile-relief materials. The high cost of production limits both the overall supply of tactile picture books

available to schools, libraries, and families with children who are BVI, as well as the diversity of materials available.

Because of the high cost of mass production, many of the tactile picture books that exist have been either crafted by hand, by braille embossers, or by swell machines to create raised line drawings. Handcrafted tactile pictures typically are raised, collage-style compositions made of textured fabric, paper, foam paper, and a wide variety of other textured materials applied to the page. Braille embossers or swell machines are used to produce raised line drawings created with general-purpose graphic design programs (e.g., Corel Drawl, Adobe Suite). Thermoform machines may also be used to make replicas of bas-relief tactile graphics and pictures; forms of objects are molded in a thin plastic sheet by heating the plastic.

Despite these tried and true production methods, the promise of a low-cost method of producing low relief and 3D tactile media—3D Printing—has piqued the interest of professionals responsible for teaching students who are BVI, e.g. ("Space.com", 2014; Kolitsky, 2014; Reynaga-Peña, 2015; Williams et al., 2014)[17]. The promise of 3D printing has also garnered the attention of access technology scholars who have shown how 3D printers can automate the creation, production, and dissemination of tactile graphics, i.e. (Brown & Hurst, 2012; Hurst & Tobias, 2011; McDonald, Dutterer, Abdolrahmani, Kane, & Hurst, 2014). While the research thus far has focused on proofs of concept, in this paper we present an effort to investigate the

[17] Soon after this study was published, Siu (2014) published the results of an in-depth survey designed to identify how professionals responsible for creating and producing tactile media for students with visual impairments view 3D modeling and printing as a resource to support their teaching practices (Siu, 2014). She found that TVIs, teaching assistants, learning specialists, college support staff, and parents see 3D printers as part of a suite of other tools used to provide accessible materials, including: pre-teaching tactile skills, Braille, tactile graphics, and image and video description. The participants indicated that 3D printing has both positive and limiting factors. Positively, 3D printing would bring imagined creations to life, enable the customization of access and assistive devices, enhance learning for all students in a classroom, and enhance the distribution and sharing of resources. However, the participants noted that in its current state, 3D printing still introduces barriers to practitioners due to the: 1) lack of instructional support; 2) safety; 3) the challenges associated with 3D modeling; and 3) the accessibility of the content being produced.

promise of 3D printing of tactile pictures in the contexts that they will be used—in the hands of teachers and parents who orchestrate co-reading experiences for young children who are BVI.

Study Design

The overarching aim of this research is to make tactile pictures more available to parents, teachers, and other invested stakeholders through the application of 3D printing. As the first step towards this goal, in this paper we present our efforts to answer three important questions:

1. What are parents' and teachers' (end-users) familiarity with tactile pictures and learning media for young children who are BVI?
2. What are parents' and teachers' (end-users) interests in 3D printing as a means of creating tactile learning materials?
3. What design strategies can be used in the creation of tactile pictures to support children who are BVI engage in reading?

To answer these questions, we engaged in a multi-staged Research through Design effort guided by principles of User-Centered-Design (UCD). Research Through Design (RtD) is a process through which researchers work out the tension between the descriptive nature of anthropological research and future-making/ interventionist research (Zimmerman, Forlizzi, & Evenson, 2007). RtD requires researchers to directly engage in the design process and practice "more rigorous documentation of progress and evolution" (Zimmerman, Stolterman, & Forlizzi, 2010, p. 316). UCD in this context calls for involving users throughout several key stages of the RtD process, including 1) Analysis or developing an understanding of the context of use and defining requirements; 2) Engaging in design activities through prototyping, validation, and iteration; and 3) Evaluating the design against the requirement (Norman & Draper, 1986). The RtD process that we report in this paper started when we began collecting participant

observations at an early intervention center serving children who are BVI and continued with the evaluation of a 3D printed tactile picture Design Probe.

Methods

The study occurred in three stages described here.

Observation

The study began with observations at the National Federation of the Blind (NFB)'s 2012 conference on Tactile Graphics. This quinquennial conference attracted circa 200 artists, teachers of the visually impaired (TVIs), transcriptionists, and representatives of organizations serving people who are BVI from all over the world. While attending, I observed that many of the practitioners were focused on creating new methods to share existing educational resources and that 3D printing was not yet a central focus of this community; many of the conversations focused on the exchange of advice about how to handle difficult scenarios or access resources for consumption[18]. My participation in this event helped us refine our research questions and shift our immediate focus to understanding how teachers and parents engaged with tactile pictures.

Accordingly, I approached an early intervention center for children with visual impairments in Denver, Colorado about volunteer opportunities in their literacy classroom. The center's teaching philosophy is based on the Expanded Core Curriculum (ECC), with an emphasis on nurturing the emotional security and the social and intellectual skills of children with a range of visual impairments. I learned that a typical volunteer position required a twice a

[18] To this point, we learned that parents and TVI's who do share information about tactile graphics often post information to listservs like the NFB-Members list, Blindkid list, BVI-Parents list, etc., Based on this observation we conducted a survey of the posts on the Blindkid list to see if 3D printing was a topic commonly mentioned on that platform. We copied all of the posts shared on the Blindkid list and BVI-Parents listserv over the course of one year and searched for the phrase "Tactile Graphics". This phrase was only referenced 15 times over the course of that year. None of these instances contained information on specific practices or 3D printing.

week commitment to building trust with students through their weekly learning activities, a commitment that I could not accommodate at the time; instead, I opted to volunteer once a month during the Center's "Parent Pullouts," a two-hour in-service for teachers and parents to exchange resources and information. During these two hour sessions, volunteers spend time in the literacy or orientation and mobility-focused classroom and had an opportunity to interact with parents and teachers. As a volunteer, I assisted the TVIs and Orientation and Mobility (O&M) teachers with students as needed.

I visited The Center 15 times over the course of six months, each visit lasting three hours. During these periods, we engaged in participant observation with the children and TVIs in the classrooms and library and held informal interviews and conversations with parents, TVIs, and other early intervention staff. After each session, I made open-ended field notes about working directly with students and the tactile materials in their learning environment. An example of one such field note reads:

> "The toddlers need much support transitioning between different stimulating experiences. They can not tell you what they need; you just need to anticipate what is going to make them move past their comfort zone. All of the kids at The Center are in very different stages and places...each required a different type of attention and kind of activity. I was told that the goal was to "stimulate" them, but not too much. When working with the toddlers today, I worked with a variety of kids. For example, I worked with a very active and explorative girl (16 months) who was exploring all over the building. She navigated through her environment using her feet to feel around and find different ground texture. When working with another student, who had a ton of energy and much functional vision, albeit distorted due to Alopecia, I was told by The Center staff to focus on keeping him

> focused on an activity for a while. With him, it was essential to give him processing time, as opposed to hounding him over and over. He is very smart, but he just needed patience. He did not use his words to communicate, in fact very few children here do. Another boy, who had very limited sight-- only bits of light, was very responsive to sound, beat, music. It soothed him; it may be that he is using his sense of sound as a resource to counterbalance his loss of sight. He had an established relationship with one teacher and seemed to need much support during transitions. The teacher said that she tries not to depend on the auditory aids all the time and to find subtle ways to help expand their comfort levels. She also said that it is very lovely when the kids are happy when the parents come back, so they do not associate their parents with relief from unhappiness. It is essential for kids to learn to support themselves."

To analyze the field notes I used affinity diagramming to identify the common themes that emerged from our observations. Affinity diagramming is a method frequently used for several different purposes in the fields of HCI, design, and anthropology to enable design teams to organize language data (ideas, opinions, issues) into groupings based on their natural relationships (Beyer & Holtzblatt, 1998; Simonsen et al., 2014). I wrote segments of the field notes on sticky notes, which we then shuffled around to find themes amongst all of the observations. The themes that emerged were: 1) TVIs Role in Emergent Literacy; 2) TVIs Familiarity with the Use of Tactile Media in Emergent Literacy Instruction; 3) TVIs Familiarity with the Design/Production of Tactile Media for Emergent Literacy Instruction; 4) Parents' Familiarity with the Use of Tactile Media in Emergent Literacy Instruction; and 5) Parents' Familiarity with the Design/Production of Tactile Media for Emergent Literacy Instruction. The results of this analysis are described in the Findings section below.

Design

After observing at the early intervention center, the first and second author of this paper began creating tactile picture prototypes, with 3D modeling application and a 3D printer, with the goal of learning how to design tactile pictures and how to use 3D printers for this purpose. As we took on the role of designers, my co-author and I identify as the primary participants in this phase of the study: RtD requires researchers to directly engage in the design process and practice "more rigorous documentation of progress and evolution" (Zimmerman et al., 2010, p. 316). At the time of this research, we were both graduate-level design researchers in our late 20s. We both had experience working in the field of design and had an interest in access technology design, but neither of us had experience teaching or working with people who are BVI. Both of us are sighted.

We choose to create tactile representations of the classic picture book "Goodnight Moon," by Margaret Wise Brown and illustrated by Clement Hurd. To create the first tactile picture prototypes based on Goodnight Moon, we referred to a collection of Tactile Graphics design guidelines (Braille Authority of North America, 2010; Edman & American Foundation for the Blind, 1992, "Tactile Graphics: A How To Guide," (n.d.). Notably, these resources were developed to support educators, disability service providers, and professional access media providers to create raised line and bas-relief graphics, not 3D media or illustrative pictures.

The first model we designed (with 3D modeling) and produced (with a 3D printer) comprised of a series of objects on a page, each of which was positioned to make the objects distinct to touch. For example, to represent the original page shown in Figure 2.1, we represented the bed in a plan (birds-eye) view and other objects in the room in a sectional view. We transcribed and modeled an image from the book using OpenSCAD, free software for creating

solid 3D CAD models. We then produced a model using a Stratasys Dimension 3D Printer **(Figure 2.1).**

Figure 2.1. First 3D Printed Prototype of a picture from Goodnight Moon.

To design the second prototype, we drew on the qualitative observations from the early intervention center. In summary, we learned that clutter reduces a person's ability to make sense of a tactile picture, especially for emergent readers who are learning to explore their environment. In turn, we simplified the design of the graphic: as opposed to composing a tactile picture page with all of the original elements, we selected one or two pictures or symbols to put on each page (**Figure 2.2**). After completing the second set of designs, we brought the second prototype to the early intervention center to get feedback on the design from four TVIs and a parent and child. We had these participants "think aloud" (Someren, Barnard, & Sandberg, 1994) as they tactilely examined the materials by touch. During this informal user study, we also collected field notes and suggestions provided by two other parents and their children. We applied insights gained through these investigations to design a second iteration of the 3D printed prototype **(Figure 2.2).**

Figure 2.2. 3D Printed Tactile Picture of Good Night Moon Prototype Testing.

Evaluation

We submitted this prototype to the Typhlo & Tactus Tactile Book Competition ("American Printing House for the Blind. n.d.). Our entry was accepted into the competition and was selected as one of the top five submissions. Through involvement in this competition, we received feedback from the judges. To document and report on this process, we collected all of the design artifacts we created, paired with the feedback from the judges and other users. Based on this feedback we further iterated on the design; the subsequent design consisted of a series of pages, with one or two objects on each page **(Figure 2.3).**

Figure 2.3. 3D Printed Tactile Picture Design Probe: Good Night Moon.

In the excitement of our success in the competition, we posted photos of the prototype on Twitter and developed a webpage to explain our design and production process (url expired). The website included a photo gallery of the tactile version of Goodnight Moon. These efforts attracted the attention of a 3D modeling practitioner at OpenSCAD who was developing a 3D braille creator. He shared information about our prototype via twitter, which resulted in an onslaught of community feedback. His retweeting of our post solicited the attention of a publisher of copyright-free children books, who shared our project on his website. This outreach led to 28 requests from self-identified stakeholders who want to improve opportunities for children and others with sensory, cognitive, or other physical disabilities, including visual impairment, dementia, and autism—a range of interest broader than our initial intent. We did not collect demographic data on these participants.

While receiving these requests, our prototypes started to take on a new meaning for us; they became Design Probes (Gaver et al., 2004) through which we could collect further information about people's lives, values, and thoughts about tactile media and 3D printing.

Probes can be small packages that can include an artifact and evocative tasks, which are given to participants to allow them to record specific events, feelings or interactions (Gaver et al., 2004). Accordingly, in response to each of the 28 requests, we sent a form that solicited feedback about their interest in the models, their impressions of the models, and their profession along with a 3D print of our refined representation **(Figure 2.3).**

Findings

In this section, I summarize the findings from these three phases of the study with respect to the research questions in the study. First, I address TVIs' familiarity with tactile pictures and learning media for young children who are BVI and their interests in 3D printing as a means of creating tactile learning materials. Subsequently, I address parents' familiarity with tactile pictures and interests in 3D printing. Finally, I address the design strategies we learned about creating tactile pictures to support emergent BVI readers.

Observations about Teachers of the Visually Impaired

TVIs Familiarity with Tactile Media in Emergent Literacy Instruction

While volunteering at the early intervention center, we noted the centrality of TVIs' roles in a child's emergent learning process and as a support for the child's entire family. Regarding their role in a child's learning process, one teacher noted feeling responsible "to help a child develop their curiosity about their environment." Another TVI shared that it is critical to engage students in a variety of sensory activities as soon after birth as possible to "hone, establish, and redirect their sense of touch." This sentiment echoes Drezek (1999) that for a child with visual

impairments, most of all, the motivation for literacy rests in interest and curiosity about the world (Drezek, 1999).

Accordingly, many of the teaching and learning activities that we observed at The Center focused on engaging the young students in direct interaction with non-representational tactile materials, or media which were innately tactile. For example, when in the "Literacy Room," the children carried books around as opposed to sitting and reading (despite a variety of tactile books available). One of the TVI's noted that "a good selection of tactile materials in a child's environment can help create a more dynamic encounter, and teaching children that information can be gained through tactile books." She also noted that there are different types of tactile media formats that contain tactile graphics and pictures, including Objects, Concept Books, Tactile Books, Braille Books, and Maps for wayfinding.

During another conversation, a different TVI described her perspectives about the use of tactile picture books. She shared three salient points. First, to support tactile literacy, all storybook experiences need to relate directly to the specific child's interests and abilities and to build on the context of their lives; "It is important to use narratives that add contextual information so that the kid makes a connection between what they have experienced and the object". Another TVI shared another sentiment: "younger kids need more literal references...references that have to do with what is occurring in their days." He provided the example, that if a student is learning about gardens, provide a book that includes a spade. Yet another TVI noted, "Regardless of how the tactile graphics and pictures are presented, they should be accompanied by an instruction manual so that parents and other caregivers know how to use the materials during co-reading experiences and ensure that child is having a worthwhile experience."

Regarding the use of Braille books, another TVI said, "Be aware of a child's level... some might just be becoming familiar with what a book is...but you can still include braille words." She also noted that there is not a hard line for when braille becomes an essential element in the book, so "start using it early as it is an end learning objective." She later said, "Introduce simple braille words...not conjunctive words to begin with (ex. moon vs. goodnight)." Finally, one of the TVIs noted that during her education she learned about Learning Media Assessments (LMA)[19] as a resource for IEP teams to learn about what tactile media will support a child's learning needs, however, she also noted "we do not provide a robust assessment of our students and the Learning Media Assessment tool does not address the use of tactile graphics or non-textual media."

TVIs Familiarity with the Design/Production of Tactile Media

Each of the TVIs we met with at The Center repetitively shared that they spend a considerable amount of time developing activities for the children they work with towards meeting the Expanded Core Curriculum (ECC)[20] goals and the Individualized Education

[19] The LMA is a tool used to evaluate the efficiency with which the K-12 student gathers information from various sensory channels, the types of general, learning media the student uses, or will use, to accomplish learning tasks the literacy media the student will use for reading and writing (Koenig, J. Holbrook, & Cay, 1995). The LMA assesses a student's learning style or the way in which he or she uses vision, touch, hearing, and other senses, either singularly or in combination, to gain access to information. The assessment is primarily used to identify the appropriate teaching method between print and Braille. For example, a child more likely to use Braille "shows a preference for exploring the environment tactically", "efficiently uses the tactual sense to identify small objects" and/or "identifies her name in Braille, and/or understands that Braille has meaning." LMA assessments are conducted on an individual basis; there are no formal evaluation methods to assess how well the outcomes of the LMA assessment meet students' needs.

[20] Expanded Core ECC is an instructional framework for K-12 students who have significant visual impairments and provides a set of competencies that support the individual to be successful in school, the community, and the workplace (Hatlen, 1996). Whereas many sighted children learn such skills incidentally through observing role models visually, students with visual impairments often need focused support (Lohmeier, Blankenship, & Hatlen, 2009). The components of the ECC are: 1) Compensatory or access skills; 2) orientation & mobility skills; 3) social interaction skills; 4) independent living skills; 5) recreational and leisure skills; 6) career education; 7) use of assistive technology; 8) sensory efficiency skills; and 9) self-determination skills(Sapp & Hatlen, 2010).

Program (IEP)[21] mandates. The TVIs also noted that they struggle to track student learning concretely, in part because their position often requires them to "split time between multiple schools or families." This division in their practice demands an ongoing assessment of the children's and families' needs, and constant evaluation of which needs need to be met first. This finding is consistent literature from the field of education, i.e. (Lewis, Savaiano, Blankenship, & Greeley-Bennett, 2014; K. E. Wolffe et al., 2002; K. Wolffe & Kelly, 2011), affirming that many TVIs struggle to meet the demands of their profession.

To offset the load of the other TVIs at the center, one teacher was in charge of adding braille and occasionally handcrafted or embossed raised-line pictures to the center's books. She referenced the BANA guidelines as a resource she draws on to guide her, but mainly she relies on "personal experience." When we asked her about her familiarity with 3D printers as a production method, she indicated that she had heard of 3D printing and was interested to learn more, but had never seen or used one. This echos the responses from the TVIs who requested a 3D Printed Design probe. "We have the capability to change the written material into Braille, but don't do a lot of pictures. We have not used a 3D printer, but think that 3D printing could enhance our ability to provide for parents." However, like the TVIs at the center, the pressure of time also emerged as a theme in the responses we received from TVIs who requested the Design Probe. For example, one noted, "I teach beginning braille readers, and it takes forever to make the tactile pictures for books." One TVI noted that the time it takes to 3D print materials themselves presents the same challenge: "We had the opportunity to see a 3D printer at a conference, but had not seen it used as shown in your pictures. We did not pursue a 3D printer is the time required and the difficulty of programming for making the 3D forms."

[21] An IEP is a resource that is created by a committee that helps teachers meet the goals set by a child's Independent Education Program (IEPs).

Observations about Parents and Caregivers

Parents' Familiarity with Tactile Media in Emergent Literacy

While volunteering at the early intervention center, we had little time to directly engage with parents or observe their co-reading/instruction practices; they were often in meetings with teachers to learn about other opportunities or the centers teaching and learning goals. However, when talking to one parent about their co-reading experiences during a break, she shared, "The tactile books I find are often broken. Too many of the flaps are ripped, missing." Another parent mentioned, "[at the child's school] there is a good selection, but it does not match my child's needs. There are awesome books at [the Center], but they do not come home." Another parent reflected, "I wish that we made more time for reading at home. We just don't seem to have the time and I sometimes don't know where to start."

This last comment echoes a comment made by one of the TVIs a the early intervention center about the challenges that parents face when engaging in reading activities with their children. "Many parents may not know how to translate the behavior of their child (adjustments, adaptations) specifically to milestones, or other behavioral cues when engaged in a reading activity." We observed several encounters where a TVI actively role modeled for parents how to engage their child in co-reading. For example, one TVI showed a parent how to guide their child's hand across the page without force. Despite the importance of these interactions, one TVI shared, "Often, the school setting is too hectic a place to share such detailed information with the parents, and we just don't have the time." Several of the parents we observed affirmed that TVIs play a significant role in helping them find teaching and learning materials.

The seven parents who responded to the design probe reported having previous experience with tactile pictures. Five of these respondents have children with a visual impairment, one with a child with autism, and one with sighted and “mechanically inclined children.” Every respondent noted that tactile books and are helpful resources to keep their children’s attention during co-reading. One of the responding parents shared, "My daughter is struggling with motivation to learn Braille. I think tactile picture books will help her develop tactile discrimination and get her interested in Braille."

Parents’ Familiarity with the Design/Production of Tactile Media

The parents we spoke to at The Center noted that they are interested in learning more about how to make tactile pictures despite the fact that they already encounter challenges in making books for their children. One mother noted, "Yes I am interested in making books but I no longer make them [books]. The time and effort are not worth the crappy outcome." Another one said "I find it easy to make tactile vocabulary books, i.e., Fish (fin, tail, gills, etc.) but nearly impossible to create a tactile fiction story with a plot. Help!" All of the parents said that they are interested and motivated to learn more about how to make tactile graphics and possible tools to streamline the process and assure success.

Tactile Media Characteristics

Throughout each stage of this research, we gained insight into the design strategies that can be used in the creation of tactile pictures to help children who are BVI engage in reading (Research Question 3). While making observations at the early intervention center, we spoke with a TVI about her design strategies. In reflection on what creates effective tactile pictures for

young children, she shared that “it is important to create a starting and a stopping point within the graphic to help the reader orient themselves to what is on the page.” She also noted that it is important to represent each object within the graphic with a distinct tactile symbol. For example, if there are nine flowers on a page, they should not be touching or overlapping. To this point, she noted “Complex images cannot be understood (at least with embossing)...Simple embossed lines are better than a chunk of embossed element. Break down the components so they can be understood separately and then intuitively as a composite. (ex. Leprechaun sitting in pot throwing gold. Create a pot, create a man (leprechaun), a piece of gold.”

In regards to designing an entire tactile picture book, the same TVI noted that when creating the book, one must first consider the whole of the story, not just the parts. She said, “What are the images trying to convey...what is the meaning...use tactility to create the concept of the book as opposed to an exact translation of the pictorial components.” Depending on the content of the book, the designer “may want to put emphasis on the characters or objects that reoccur and can be used to represent a change in the narrative.” She also noted that for young children it is important to use real objects and to put a copy of the same graphics or object on each page to create a common reference point that the fingers can find. For example, in Eric Carle's book, The Spider and the Fly, there is an embossed fly on every page.

In addition to learning about the aforementioned considerations regarding tactile literacy, while at The Center we conducted an informal analysis of the books in their library. In line with the TVIs anecdotes, we noted that many of the tactile learning materials included raised line tactile representations that were simplified or abstracted from the original image. We also found that many of the tactile books in the collection included objects that were the same scale or in

original likeness to the real object. Furthermore, the tactile pictures contained within the books contained a range of textures, high contrast, and in some accompanying sound triggers.

While designing the initial prototypes, we attempted to apply these insights gained from our observations. We quickly realized that it is easy to fixate on 3D modeling little details within the design, rather than the larger learning goals or the tactile experience. The prototype we submitted to the Typhlo & Tactus Tactile Book Competition evidenced this design fixation. One of the competition judges noted, "only one or very few objects should be shown per page." The feedback also included praise and critique of our efforts to use 3D printing as production technology, e.g. "very interesting possibilities," "keep exploring it [3D printing of tactile pictures]," and "the plastic models are harder to interpret than rich textures."

We also received feedback on the final prototype (design probe) that we sent some of the respondents. Those we heard back from shared that they liked that we tactically distinguished different elements on the page through the use of different design decisions, i.e. we modeled a mouse sitting upright so the user could feel the whole body. The respondents asked for more detail on some of the objects, such as a tail of a mouse, which is the key characteristics of the animal, as well as vivid and contrasting colors on the model. Many respondents indicated that parts of the 3D models are easily removed from the base page, indicating that our current 3D models are not designed robustly enough. This feedback challenged us to define the correct key characters of objects precisely while creating models simple enough to minimize other trivial features.

Discussion

Familiarity with Tactile Pictures- Materials and Design

Our qualitative observations and the dissemination of the Design Probe revealed several interesting insights related to our first research question, “What are parents’ and teachers' familiarity with tactile pictures and learning media for young children who BVI?”. First, we found that TVIs are deeply committed to cultivating young children’s skills to explore their environments and make sense of information through non-visual senses. In fact, the TVIs that we spoke with at the early intervention center emphasized the importance of developing activities and tactile media that uniquely meets a child’s interests and learning needs. TVIs are well versed in developing such activities to support children's exploration of their environments; however, the time that is required to design new tactile materials is often very limited.

Along with developing activities, an important aspect of any early childhood TVI’s job is to communicate and coordinate with parents about their students learning milestones and the teaching and learning strategies that will support their development. In fact, one TVI recommended that all tactile pictures that are brought home have an instructional manual so that parents and other caregivers know how to use the materials during co-reading experiences and ensure that child is having a worthwhile experience.

The parents and other caregivers that we observed at The Center appeared to be less familiar with the range of tactile learning materials available for young children. We observed that these parents are eager to find resources that will support their children's learning, but like TVIs, they strain to find the time to create their own materials. Parents often depend on their child’s TVI to learn about learning resources for their child, national organizations like the NFB, and occasionally social media sites like Pinterest for inspiration.

While there are resources and guidelines available to parents and teachers interested in creating tactile graphics, only one of the TVIs we interacted with mentioned these resources. While these resources are available, we found that using these guidelines during the design process is confusing. In addition, many of these guidelines focus on scientific and mathematical graphics, and require time and dedication to master; even identifying how a tactile representation will best complement the storyline can be confusing and time-consuming. All the while, there are few forums for teachers, parents, and artists to share how they apply these guidelines to their craft or the actual materials they created. In some cases, there are tactile graphics specialists to create individualized content for children and support the teachers, but this is rare due to budget allocations.

Interests in 3D Printing

The parents and TVIs of young BVI students whom we interacted with directly as well as through the deployment of the Design Probe all expressed interest in 3D Printing as a production technology for tactile pictures. Despite this enthusiasm, however, 3D printing is still a new concept for them; they had not yet seen or used 3D printing in practice. Furthermore, while the prospect of using 3D printing to produce tactile materials was appealing, they recognized that learning to use the printers as well as the 3D modeling programs needed to design the materials would take time—something they did not have.

Our investigations also revealed that while TVIs and parents were interested in the technology, they were concerned that using 3D printers to create tactile pictures would miss some of the important attributes of early learning media. For instance, tactile pictures and other emergent reading materials for young children need to have realistic textures, contain life-size

objects that are familiar in their daily lives (e.g. a toothbrush, a comb, a shovel), and entice a child to explore. Specifically, the Typhlo & Tactus Tactile Book Competition judges noted that a child will only feel one material if the book is produced with a 3D printer, whereas handmade tactile pictures often have multiple textures.

Our investigations did reveal, though, that there is a growing interest in 3D printing as a viable production method for creating tactile pictures and tactile graphics for older students. In addition to soliciting feedback from parents and TVIs, the Design Probes we sent out attracted the interest of other stakeholders. Three braille transcriptionist and tactile designers who work for public schools requested copies of the 3D printed prototypes for their elementary aged students. They report that they are working on behalf of students in need of this technology and are excited about the promise of 3D printing. "We also have 3D printers at several of our schools, and I am seeing great promise for the possibility of producing our own 3D tactile books in the future." They also disclosed their current practices and needs for 3D printing—“I currently use Swell Touchpaper to make raised-line images or try to find pre-made, small-scale models"—and describe themselves as a bridge of information to others in their profession—"I promise I would share your book with others. I'd just love to see (and feel) it!"

The 3D printed probes also drew the attention of a variety of other community members, including people working in institutions of higher education, within the medical profession, and at non-profit organizations. We received inquiries from scholars from different fields of study (developmental psychology, art and design, photography, and cognitive science), the majority of whom work directly with people with visual impairments and wanted to share information with their BVI colleagues. Some indicated their specific domain interest, including interactive mapping, tactile perception research, design research.

Other scholars requested the Design Probes to display at upcoming events to promote the use of 3D printers or advanced methods within the domain of STEM education for people with disabilities. One of the respondents was looking for new methods to inspire students to focus on diverse populations. "Our students opt for careers working with special needs youth. The tactile nature of these books would appeal to the students as hands-on learners." We received a range of additional requests from people that identified themselves with other communities and see an application of our work. For example, a unit manager of a long-term nursing center working with residents with dementia was looking for sensory items for their residents. Another respondent works for an NGO that provided arts and accessibility services to people with disabilities and wanted to use 3D printing. Other respondents indicated working for their town libraries and yearned to create learning opportunities for patrons.

Tactile Picture Design Strategies and Socio-Technical Opportunities

We began this research project with the goal to make tactile pictures more available to parents, teachers, and other invested stakeholders through the application of 3D printing. In the framing of the project, we did not specify what kind of pictures or the age of our intended child-users. However, through developing a relationship with an early intervention center for children who are BVI, the context of our investigation became more clear: we were researching the employment of tactile pictures for toddler and preschool students. While the Design Probe revealed insights about a broader user-group's interest in 3D printing tactile pictures and graphics, much of the data we collected centered on emergent readers (via their parents and teachers). In this section, we summarize the tactile picture design strategies we identified for this population, as well as adjacent socio-technical design opportunities that take into account the

parents and TVI's familiarity, interests, and availability to engage in the creation of tactile pictures.

While volunteering at The Center and while engaging in the design of the early 3D printed tactile picture of Good Night Moon, we learned first hand about some of the challenges of designing effective tactile pictures for emergent literacy situations. We noted that there are many factors that need to be considered prior to starting the craft process (regardless if the craft process is with cardboard and wiki sticks or a 3D modeling application). First, it is important to know who you are designing for. What is the age of the child you are designing for, what are their interests and tactile sensitivities, etc.? For young readers, tactile pictures need to be simple, include realistic materials and shapes, be durable, and be designed with a clear message in mind. While this is not at all unique to the design of tactile pictures, historically many assistive and access technologies have not been designed through the direct involvement of people with disabilities. Second, it is important to consider how to support the parent in knowing how to effectively co-read with the materials. Young children get the most out of reading experiences when they are directly engaged by a parent, sibling, or teacher. These considerations do not change whether tactile pictures are being produced by hand or 3D printers.

To this point, during our UCD process, we envisioned a tool that would support TVIs and parents create age and interest appropriate material together with their child. Imagine a mobile application that would periodically ask parents and TVIs a series of questions about the young readers' interests, learning needs and developmental milestones and tactile preferences. On the surface, the application would serve as a record keeper and communication aid between TVIs and parents. As one TVI in our study noted, despite the fact that one of their core responsibilities is to be in communication with parents about the child's progress, sometimes it is a struggle to

share their detailed observations of a child's progress in gaining tactile acuity and other emergent literacy skills. All the while, the application could draw on this data and curate a collection of age-appropriate materials that a parent or TVI could assemble into a tactile picture book with their child. A team of designers would draw from a library of parts to compose a tactile picture book. A week later the TVI or parent would receive a package of 3D printed and handcrafted parts that they could assemble with their child into a tactile picture book.

The aforementioned idea draws on another concept: A 3D tactile picture digital library, with downloadable parts. We propose the design of a digital library of 3D printable parts and a community forum where for tactile picture readers and designers can share their experiences and help validate the materials generated by other designers. While organizations like the American Printing House and the Royal National Institute of Blind People in England currently maintain digital archives containing raised line tactile graphics, there are restrictions on who can use these graphics and much of the material is oriented to older students. Furthermore, these repositories do not focus on building a community around the exchange of tactile pictures.

Finally, while investigating the design of tactile pictures for emergent literacy learners, we found that it was difficult to keep track of where and how young children tactilely explore the page. As designers, we yearned for data reflecting the position of their hands and the exploratory procedure they were using. Towards this goal, we propose embedding touch-receptive sensors and/or conductive paint onto the surface of the 3D printed models to obtain immediate feedback (finger touch spots) about what part of the images attract a child's attention. These "Sensing Tactile Pictures," would provide designers, parents, teachers, and researchers feedback about their child's engagement with the book that may otherwise go undetected.

Conclusion

The initial and overarching objective of the research presented in this paper was to investigate how to make tactile pictures more available to parents, teachers, and other invested stakeholders through the application of 3D printing. As computer science and design researchers unfamiliar with the needs of tactile readers and their caregivers, yet interested in accomplishing this goal, we engaged in a multi-staged RtD process to learn more about parents' and teachers' familiarity with tactile pictures and learning media for young children who BVI, their interests in 3D printing as a means of creating tactile learning materials, and successful tactile picture design strategies. As part of our RtD process, we volunteered at an early intervention center for children who are BVI, developed and evaluated 3D tactile picture prototypes with end users, and deployed a refined Design Probe into the broader community.

Our research efforts revealed that TVIs who work with young children are very familiar with tactile pictures and other learning media and that TVIs are very important in the lives of families with children who are BVI. Our efforts also revealed that while 3D printing may not be the most appropriate production material for emergent literacy learners, parents and teachers alike are very interested in its application to tactile graphics, particularly for older students. Accordingly, these findings require us to reframe our initial and overarching objective to be more specific, e.g. what kind of tactile pictures and for whom. All the while, our efforts revealed that there are broader design opportunities to support emergent literacy learners and alleviate the lack of emergent literacy materials. While our initial and overarching objective was not directly achieved through this research, our findings affirm the importance of grounding technical innovation in a solid understanding of the needs of the users you are designing for.

CHAPTER 3:

TRANSCRIBING ACROSS THE SENSES: COMMUNITY EFFORTS TO CREATE 3D PRINTABLE ACCESSIBLE TACTILE PICTURES FOR YOUNG CHILDREN WITH VISUAL IMPAIRMENTS

Prelude

The research I presented the previous chapter, Chapter 2, focuses on an investigation of parents' and teachers' familiarity with tactile pictures for young, emergent readers who are blind and visually impaired (BVI), and their interest in 3D printing as a method for producing tactile pictures to support emergent literacy and co-reading practices. One finding from this study illuminated that parents, teachers, and other community stakeholders are interested in learning to use 3D printers to create tactile media--despite the fact that 3D printing may not be the best method for creating emergent literacy materials and that other possible socio-technical designs may more directly support parents, teachers and their children in their co-reading activities.

As a result of this first study, I became enthralled with investigating how to make the task of designing and producing tactile pictures for students of all ages more approachable, especially at a time when parents, teachers, and other stakeholders were speculating that 3D printers could be used to create tactile pictures and graphics. After engaging in the design of tactile pictures, as described in that chapter, I came to see that designing effective tactile pictures that can be 3D printed is a design task that requires many different considerations that are not addressed in the existing tactile graphics guidelines, i.e. (Braille Authority of North America, 2010) or shared

publicly; much of the existing knowledge that exists about tactile media design is held by practitioners has not been formally reported on.

Accordingly, my colleagues Caleb Hsu and Dr. Tom Yeh and I set out to identify what groups of stakeholders were interested and invested in the creation of tactile pictures for people who are BVI, as well as their motivations, skills, and approaches to the design task. In this Chapter I present the findings of this investigation, which were originally published in a paper titled "Transcribing Across the Senses: Community Efforts to Create 3D Printable Accessible Tactile Pictures for Young Children With Visual Impairments" in the Proceedings of the Conference on Computers and Accessibility in 2015 (Stangl, Hsu, & Yeh, 2015).

To identify the stakeholders and to understand their motivations, skills, and approaches to tactile picture design, I led the design and implementation of a series of tactile picture design workshops that directly a variety of stakeholders in the design of tactile pictures through the use of 3D modeling applications and hand-craft. We conducted six workshops, with N=67 participants in total, as a context through which to observe patterns that are important and relevant specifically for the conception, design, and development of new products and services (Salvador, Bell, & Anderson, 1999), e.g. conduct a design ethnography focused on tactile pictures.

This study illustrated: 1) the stages of design involved in designing and 3D modeling tactile pictures, 2) the motivations and approaches different stakeholder groups used to attempt if not complete the design task, and 3) the different skill levels the participants brought into the design experiences. While conducting the workshops, I became interested in how each of the stakeholder groups' skills and approaches to designing tactile pictures could be leveraged to inform new approaches to increasing the supply of tactile pictures for people who are BVI; I

proposed the design of an online creativity support tool to help offset the challenges of designing and 3D modeling tactile pictures that can be 3D printed.

Since publication this paper has been cited 15 times by Human-Computer Interaction (HCI) scholars, who research and write on creativity research in HCI e.g. (Frich, Mose Biskjaer, & Dalsgaard, 2018), 3D printing of assistive technologies e.g. (McDonald et al., 2016), 3D printed tactile learning media e.g. (Holloway, Marriott, & Butler, 2018; Reichinger, Carrizosa, & Travnicek, 2018), the design of 3D modeling systems (Suzuki, Yeh, Yatani, & Gross, 2017; Yeh & Kim, 2018), and the design of materials for inclusive learning environments e.g. (Buehler, 2018; Giraud, Truillet, Gaildrat, & Jouffrais, 2017; Nishino, Podari, Sini, Edirisinghe, & Cheok, 2016). To the best of my knowledge, this is the only paper published that employs design ethnography to explore and illuminate the design practices and considerations of people involved in tactile media creation.

Abstract

The design of 3D printable accessible tactile pictures (3DP-ATPs) for young children with visual impairments has the potential to significantly increase the supply of tactile materials that can be used to support emergent literacy skill development. Many caregivers and stakeholders invested in supporting young children with visual impairments have shown interest in using 3D printing to make accessible tactile materials. Unfortunately, the task of designing and producing 3DP-ATPs is far more complicated than merely learning to use personal fabrication tools. This paper presents formative research conducted to investigate how six caregiver stakeholder-groups, with diverse skill sets and domain interests, attempt to create purposeful 3DP-ATPs with amateur-focused 3D modeling programs. We expose the experiences of these stakeholder groups as they attempt to design 3DP-ATG for the first time. We discuss

how the participant groups practically and conceptually approach the task and focus their design work. Each group demonstrated different combinations of skill sets. In turn, we identify the activities required of the design task as well as how different participants are well suited and motivated to perform those activities. This study suggests that the emerging community of amateur 3DP-ATP designers may benefit from an online creativity support tool to help offset the challenges of designing purposeful 3DP-ATPs that are designed to meet individual children with VI's emergent literacy needs.

Introduction

Emergent literacy is the process in which a young child constructs concepts about the function of symbols and print. It is based on experiences and meaningful language facilitated by interactions with adults. For sighted children, pictures and illustrations provide a bridge between listening and early reading behaviors. These visual stimulants play a significant role in enriching the storyline and adding humor and intrigue, giving instant clues that enable the reader to reconstruct the story. Children only gradually become aware of the text over time; it is the illustrations that help a child recall the meaning and words of a story (Lewis & Tolla, 2003).

Children with visual impairments (VI) often miss the opportunity to learn from illustrated children's books because their perception is limited to what can be felt by the hand, seen within a limited visual field, and heard. Children with VI often have difficulty understanding the gestalt, or whole nature of experience (Cay Holbrook & Koenig, 2000). Accessible tactile pictures (ATPs) consist of tactile representations that convey different kinds of messages and present information through the sense of touch to further a child's cognitive-affective and relational development (Claudet & Richard, 2009). Successful ATPs for young learners (kindergarten through 3rd grade) focuses on representing content in a tactile manner that builds a younger

child's understanding of symbolic representation and confidence to explore their environments and make associations through the sense of touch (tactile acuity). They can be used during co-reading experiences between a caregiver and a child, and help convey relationships, concepts, and story objects relevant to the child's learning. Reading and play with ATPs an essential role in developing emergent literacy skills in young children with VI because they support joint attention with a child reads with caregivers (Stratton, 1996), offer children with a means to be an active participant in the reading experience, and offer opportunities for interaction with their peers. ATPs and ATGs are most successfully used alongside other verbal description of the story.

The Braille Authority of North America (BANA) indicates that solid shapes are more easily recognized than an outline of shapes and objects for young readers, who are learning emergent literacy skills (Braille Authority of North America, 2010). If designed well, ATPs can support one's learning from part to whole, and help prepare children with VI to make a stress-free transition to accessible tactile graphics (ATGs), which blind learners are likely to use as they advance in their education (Claudet & Richard, 2009). ATGs focus on conveying science, technology, engineering, and math (STEM) topics, which are commonly transcribed representations of diagrams, charts, maps, and drawings.

The design of ATPs and other accessible materials, like the design of many assistive technologies (AT) (Hook, Verbaan, Durrant, Olivier, & Wright, 2014), greatly benefits from the consultation and involvement of end-users and their caregivers. Of late, many caregivers and other stakeholders of children with VI have identified the opportunity of 3D printers to make low-cost, highly customized tactile forms, objects, and books containing 3D printed accessible tactile graphics (3DP-ATGs), and 3D printed accessible tactile pictures or illustrations (3DP-

ATPs) (Siu, 2014) **(Figure 3.1)**. Unlike traditional ATG and ATP production methods (embossers, thermoform, handcraft) 3D printing allows for the rapid production of solid forms and personalized ATPs. However, despite the growing popularity of 3D printers and their affordances, the complexity of the design task creates a barrier to using 3D printers for creating ATPs.

Figure 3.1. Top: Handcrafted 2.5D-ATP/ATG (Source: Perkins School); Bottom 3D Printed 3DP-ATP.

In this paper, we present formative research to identify how caregivers and stakeholders of people with VI engage in the design practice of making accessible 3DP-ATPs and how they innately approach 3D modeling, tactile graphicacy, decoding, and other skill sets to achieve the design task. Through conducting six workshops, with 67 participants in total, we observed the

workshop groups' abilities and conceptual and practical approaches to transcribing visual pictures into meaningful 3D tactile experiences.

While no one participant group fully accomplished the design task during the workshops, we noted a clear division in the groups' approaches, and thus propose how different stakeholder groups' abilities can be leveraged to accomplish the multidisciplinary design task. We expand upon the previous work on assessable tactile and sound-based materials for people with VI, and 3D printed assistive technologies (AT). This research also contributes to an ongoing effort to design and develop an online digital library and creative collaboration tool that bridges the social and design capital those committed to supporting emergent literacy.

Background

ATG and ATP Production and Supply: Organizations serving blind communities have been making children's books for VI children for years. In the United States, publishers, e.g., American Printing House for the Blind (APH) and National Braille Press (NBP), and tactile graphic artists have been the primary producers of ATGs and ATPs. NBP carries a catalog of 100+ children's books ("National Braille Press," n.d.) and Seedlings, a nonprofit organization dedicated to providing low-cost Braille books for VI children, has a catalog of 1,200 titles ("Seedlings Braille Books for Children," n.d.). In addition to the mass produced books, several organizations in the United States and Europe have organized ATG and ATP book competitions to entice artists and other stakeholders to create new material ("American Printing House for the Blind," n.d.).

However, the supply of these books is limited due to the time and cost involved with designing and validating the content, creating the thermoform and other subtractive molds, and subsequently producing the material in bulk. Many of the books that are produced are oriented to

older children and do not contain purposeful representations for those who have not yet learned Braille or more advanced decoding skills. Furthermore, much of the material is not easily customized to meet the unique learning needs of an individual child. In turn, when purchasing traditional ATPs and books from publishers or artists, caregivers often face a tradeoff between cost, supply/selection, and appropriateness for their child's unique needs.

Need for Individualized ATPs: Many teachers of the visually impaired (TVIs) advocate that ATPs should be designed for the individual, specifically focusing on creating material that focuses on specific skill development and the knowledge needed to comprehend them (Aldrich, Sheppard, & Hindle, 2003, p. 284); Learning tactile and haptic perception and acuity varies hugely based on their cognitive abilities as well as their learning environments. The caregivers (parents, TVIs, etc.) and artists who choose to take the time to make ATGs and ATPs for individual children manually have traditionally used a wide variety of textured materials, including textured fabric, paper, foam paper, and the like. These ATPs are often fragile and are not easily reproduced.

Of significance, the development of emergent literacy skills four young children with VI is not solely dependent on the use of ATPs. Students need assistance in interpreting the information being presented in ATPs. Best educational practices include additional activities to help individual children match pictures to sounds, letters, words, and the environment around them. A variety of touch graphic technologies providing non visual feedback, including but not limited to, The Talking Touch Tablet (Landau & Wells, 2003), Talking Tactile Pen (Landau, Bourquin, Miele, & Van Schaack, 2008), QR Codes to Access (Baker, Milne, Scofield, Bennett, & Ladner, 2014), that have been developed to embed various interfaces with auditory information that help individuals interpret information.

ATG and ATP Design Guidelines: For those who focus on designing ATP for bulk production or individual users, alike, there are resources available to guide their design work. The BANA guideline, provide ATG designers and braille transcriptionists with best practices and conventions for raised line/ 2.5D tactile representations, including considering the cognitive obstacles to peoples' successful use of ATG and ATP; touch cannot discriminate the fine detail that sight can; extract information through a sequence of touches and then re-integrating it imposes a heavy memory load; assure that conceptual graphical representation are augmented with interpretation (Braille Authority of North America, 2010). Like visual picture illustration, however, there is no single approach to designing ATGs and ATPs, and the guidelines will only go so far to inform one's design process. To the best of our knowledge, no formal work has been conducted to evaluate how or if caregivers and other stakeholders design ATPs according to the recently published guidelines, or whether the existing 2.5D guidelines apply to the design of 3DP materials.

Albeit, many TVIs, artists and other designers of ATG agree that when transcribing a graphic illustration into an ATG and ATP, graphicacy aids one's ability to create meaningful materials. Graphicacy depends on one's ability to decode graphics elements (Aldrich, 2008). Aldrich suggests activities for teaching tactile graphicacy should include refining the scope of graphic formats being taught, strategically selecting contextual examples of graphics, presenting multiple versions of graphics representing similar concepts, prompting students to think of the merits of different formats, and providing opportunities for students to gain their own hands-on experience with designing (Aldrich et al., 2003). To this point, BANA states, "the best method for learning how to prepare a tactile graphic comes from hands-on training, from critical

feedback from other tactile producers and tactile graphics readers, and from experience (Braille Authority of North America, 2010)."

Related Work

3D Printing ATG: Recent work has focused on the feasibility of using 3D printers to create AT and tactile materials (Buehler, Kane, & Hurst, 2014; Kolitsky, 2014) however, many of these efforts only concentrate on the material feasibility of 3D printing STEM-focused tactile graphics or the interest of the community in using the technology, as opposed to issues of accessibility (Stangl, Kim, & Yeh, 2014). Some scholars discuss the limitations of 3D printers for the production of tactile graphics and pictures due to the resolution of the prints highlight some potential limitations of the technology. However, recent advances in technology designs are eliminating these concerns. Hudson shows that 3D printers are not limited to printing plastic (Hudson, 2014).

AT Requirements: Several efforts have focused on the feasibility and requirements for using 3D printing in the context of serving populations with varying ability, including individuals with cognitive, motor, and visual impairments. Buehler et al. explored how 3D printing can address the concerns of designing AT and customized solutions for young students in special education environments (Buehler et al., 2014). They identified requirements for making 3D printers accessible to learners and caregivers in such environments, including: make accessible software, consider the learning curve, encourage sharing of existing models, and support editing existing models. McDonald et al. discussed how digital fabrication can support the creation of educational aids for providing accessible curriculum content (McDonald, Dutterer, Abdolrahmani, Kane, & Hurst, 2014).

While these efforts provide significant insight into the requirements for using 3D printers in special educational contexts, they do not discuss the range of stakeholders involved in approaching a specific AT instructional design task with 3D printers. Hook et al. conducted interviews with 11 caregivers to explore the challenges that are, or might be, faced by non-professionals when making DIY-AT (generally) and the challenges of making DIY-AT for children with disabilities (Hook et al., 2014). This research revealed the community's value of rapid prototyping technologies and the need for the creation of practical communities to help lower the barrier of entry for caregivers with little technical experience. They recommend an increase in practical services and communities that support and encourage more substantial numbers of non-professionals to become involved in making and adapting AT. To this point, Buehler et al. present a systematic evaluation of assistive technology creation and dissemination in an online community of assistive technology makers on Thingiverse (Buehler et al., 2015). They found that many of the shared DIY assistive technologies are created by people with disabilities or on behalf of friends and loved ones and that these designers frequently have no formal training or expertise in the creation of assistive technology. Their findings did not include information related to the activities people engage in designing materials for children with VI, but they do call for efforts to engage people in the design of AT.

DIY AT Design Tools: A variety of efforts have been taken to design digital tools to support caregivers, stakeholders and people with disabilities designing AT (De Couvreur & Goossens, 06/2011; Hurst & Tobias, 2011). However, we have not found any project that supports users in creating 3D printable 3DP-ATPs for young children. In recent years, there has been a rise in the development of 3D digital fabrication tools for education and amateur users to lower the entry point to learning 3D modeling, in general. SketchUp, and 123Design have been

designed to lower the threshold of learning for novice users while providing professionals a high ceiling for use. Unlike traditional 3D modeling programs (Rhino, SolidWorks, Maya), amateur-focused tools tend to hide the underlying geometrical figures, algorithms, and vectors of the objects. Lastly, the CHI and IDC communities have focused on developing constructivist learning through 3D modeling with alternative inputs, including the UCube (Leduc-Mills & Eisenberg, 2011), KidCad (Follmer & Ishii, 2012), and FabCode (Agrawal, Jain, Kumar, & Yammiyavar, 2014). Zeising et al. propose a series of criteria for a new wave of constructivist-based digital fabrication (modeling) software design, which, if applied, may continue to reduce the barriers of entry into 3D modeling (Zeising, Katterfeldt, & Schelhowe, 2013). All of these efforts have yet to build in support features for designing ATG/3DP-ATP.

Research Method

Our principal research questions regarding the design of 3DP-ATP for children with VI are: (1) What distinct stakeholder groups are interested and willing to contribute to developing 3DP-ATP, and how/what do they contribute; (2) How do these groups differ and what do they have in common in terms of motivation, design approach, and skill; (3) How can distinct stakeholder groups' skills be leveraged to increase the supply of 3DP-ATP?

Participant Recruitment: Stakeholder Groups

Background: Before this work, our team designed, and 3D printed a series of 3DP-ATP prototypes. Through word-of-mouth and news media coverage, we received a large number of email requests from various people for samples. We subsequently delivered samples to meet a subset of these requests, limited to those who self-identified as parents or teachers of VI children because they were our priorities (Stangl et al., 2014). Informally, many recipients told us that, if

possible, they would like to learn and be able to design and make 3DP-ATPs on their own. A majority of the requests came from parents or TVIs. However, we also received a significant number of email inquiries from other sorts of people not traditionally associated with the blind community. Many expressed a strong desire to help design and make 3DP-ATPs. Before this work, we had not yet made a systematic attempt to understand who they were, what they might be able to contribute, and how their knowledge or skills may complement those of the parents and TVIs. We intentionally decided to exclude parents from this research due to another concurrent study focusing on how parents approach the design of ATG and other AT.

Participant Selection: First, we revisited all of the email requests we received, paying specific attention to those coming from people other than parents, TVIs, or blind people. We clustered the emails based on the job titles of the senders. In many cases, the sender would self-identify his or her job title. In other cases, we could infer the job title from the body of the message. We were able to identify clusters of librarians, retired-volunteers, engineers, students, artists, and reporters. This process gave us a rough idea of what "other" stakeholder groups might exist. I revisited all of the email requests we received in response to the 3D printed design probes and clustered the emails based on the job titles of the senders. Next, we advertised to local communities such as libraries, schools, volunteer centers, art galleries, and maker spaces, to offer workshops on 3D printable 3DP-ATPs at their sites. We intended to find a local representation of each of these other stakeholder groups to study them in depth. Our outreach effort attracted six distinct local participant groups interested in running design workshops at their site, including a group of children librarians (n=6), a group of accessible media librarians, (n=6), a group of engineers with interest in supporting people with VI (n=3), a group of interaction designers

interested in supporting people with VI (n=4), a group of volunteers who work at an accessible media library (n=7), and a group of TVIs and orientation and mobility (O&M) specialists (n=40).

Workshop Design

To design a workshop experience where participants could learn and use digital fabrication tools to explore, develop, and share their perspectives about the design of accessible learning media, I drew upon the concept of intelligent making (Bunnell, 2000). Intelligent making proposes a mix of formal knowledge, tacit knowledge, physical and mental skill, contextual awareness, innovation, and personal creative autonomy. It is well regarded that direct experience stimulates the imagination and provides anticipatory knowledge leading to the performance in the creative act of making **(Figure 3.2).**

Figure 3.2. Workshop Activities: Discuss, Explore, and Model).

To engage participants in 'Intelligent Making,' I planned a series of hands-on activities where participants could experience existing tactile graphics and picture materials, compare their touch-based experiences, and reflect more deeply on the requirements of making tactile pictures. I scoped the design task to focus on the transcription of existing pictures and books so that

participants were not required to conceive of original drawings and narratives to support their compositions.

Macintosh laptop computers and wireless mice were available for participants to use, and those with prior 3D modeling experience were encouraged to use their preferred software and tools. Before the workshops, our team completed a heuristic evaluation of five 3D modeling programs oriented to novice designers (Tinkercad, SketchUp, FreeCad, OpenSCAD, and 123D Design), the associated navigational and design tools, and their compatibility with producing STL files. The evaluation was conducted to inform the selection of the modeling tools to be presented and taught during the workshops. We used a five-point scale (1=intuitive, 2=easily learned, 3=moderate, 4=challenging, and 5=impossible) to evaluate the tools. We selected two tools to use during the workshops: Tinkercad (1.5) and SketchUp (2.5).

Each workshop was planned to last four hours; an hour and a half were allotted to introducing the design task, followed by two and a half hours of modeling/design work. Of note, each workshop was designed to follow the same structure. However, we prepared for an adaptive workshop structure to suit each stakeholder group's emergent needs. The base structure of the workshops progressed through:

- A sudden blindness activity, where blindfolded participants explored existing tactile graphics, pictures, and other materials through touch.
- A rapid prototyping activity, where participants would visually analyze simple picture books such as Good Night Moon and The Very Hungry Caterpillar, and then transpose the graphic into a tactile representation using clay and craft supplies.
- A tutorial that guided participants through a 3D modeling software installation process, demonstrations of the 3D modeling tools (navigation, shape, etc.)

- A tutorial on Thingiverse, an online STL repository, and resource for finding, saving, and sharing models.
- Openwork time, and time to explore 3D printers.

Data Collection

In order to answer the research questions, “What perspectives, motivations, and skill sets do each group bring to the task?” and “What do their commonalities and differences reveal about tactile media design?” we asked participants to “think-aloud” (Someren, Barnard, & Sandberg, 1994) while engaged in each of the different activities. While facilitating the workshops I took and wrote field notes and captured video of think aloud sessions and the discussions that occurred between participants.

Data Analysis

Immediately after each workshop, we formalized our notes by writing analytical memos that focused on participant concerns and considerations while approaching the design task, and while engaging in 3D modeling. Immediately after each workshop we also ranked each participant and participant group and their dominant skill sets among all participant based on observations of how they:

- Considered end-users needs and development;
- Considered principles related to emergent literacy;
- Drew from tactile media design considerations;
- Engaged in task management;
- Demonstrated basic proficiency using 3D modeling tools.

We subsequently used this schema to analyze video from the workshop and identify each groups' commonalities and differences pertaining how they made sense of the design task and how they engaged in the 3D modeling activities (practice). We also identified the different roles the participants in each group took on and their competence in different skill areas.

Findings: By Workshop Groups

Accessibility Librarians

Group Overview: Seven librarians from the Colorado Talking Book Library, where audio resources are recorded and provided to patrons with VI, participated in the workshop. The director of the library contacted us to inquire about our methods of creating 3DP-ATPs and to see if they were available for contribution. We agreed that a workshop would be a good way for the library's employees to learn more about 3D printing.

Prior Experience: The seven participants had a range of technical knowledge and skill for transcribing books into audio, but had no experience with 3D modeling, 3D printing, or transcribing books into a tactile format. Each participant was accustomed to interacting with visually impaired patrons at the library or on the phone daily.

Workshop Adaptations: Participants quickly lost focus and interest during the demonstration of 3D modeling, and asked to look at and touch some books before modeling.

Design Task Findings: The librarians spent an hour discussing the books (Goodnight Moon, Five Little Ducks, Each Peach Pear Plum, and The Very Hungry Caterpillar) and the constructs of a visual image and story. As a group, they identified the graphical elements and discussed how to convey these elements through means other than sight. One librarian said, "We should ignore elements of illustration that would distract from understanding the meaning of the

story. We should not worry about appearance as much as general shape." When exploring how to convey emotion, another asked, “Is a teardrop enough? Maybe this is a story where a paired reader is with the VI child to establish context.”

The group began to establish a set of their own guidelines to help with the task of transcribing illustrations, including 1) observe the patterns of object/image repetition (e.g., movement, repetition, and progression); 2) take note of the social relationships established in the book's imagery and narrative; 3) observe how numeric and language literacy skills are being developed; 4) observe how emotions are conveyed in the story; and 5) recognize the historical and cultural context of the book and make representations that are relevant to a child's current context. The Talking Book librarians also reflected on the philosophical challenge in prioritizing illustration over text and the challenge to think about honoring the perspective of a person with VI.

Modeling Task Findings: To simplify the modeling work, we opted to demonstrate how to import models from Thingiverse into TinkerCad and subsequently how to use the tool to compose a page of tactile elements. All participants collectively elected to model one page from Goodnight Moon by ignoring elements of illustration that distract from understanding the meaning of a story. One participant suggested that “We should not worry about appearance as much as general shape.” While importing models from Thingiverse into TinkerCad and trying to place them on the "page" all participants struggled with differentiating between scaling and moving an object vertically. The use of navigation and orientation tools to improve the modeling experience was unintuitive for the participants. Some had difficulty using the zooming feature, while others were confused about saving and accessing their models on TinkerCad. Even though most of the participants struggled to get "the program to do what I wanted it to do,” all were

satisfied with the experience at the end of the workshop. One librarian said that "This technology has much potential for helping our community access their world."

Children's Librarians

Overview: The Boulder Public Library acquired a new 3D printer for their teen makerspace and reached out to our research team to learn more about the applications of the technology. Eight early-literacy librarians who were knowledgeable about reader engagement, literacy development, and children's books were keen to develop literacy-based materials and 3D print.

Prior Experience: Aside from the workshop coordinator, none of the librarians had previous 3D modeling or printing experience. All of the librarians worked with young children and their families' daily; they had infrequent visits from blind patrons.

Workshop Adaptations: Before the workshop, the library coordinator proactively created a plan to follow to maximize the use of time. She also began a conversation with her coworkers in preparation for the workshop, during which the librarians collaboratively chose three books to model: Windblown, Where the Wild Things, and Anton Can Do Magic. The books were selected because they represented three different reading levels and communicated the Every Child Ready to Read (ECRR) principle of "Play." We choose Play as a central topic because of the embodied attributes of the theme and the opportunities for representing interactivity in a variety of ways. When describing their rationale for this during the introduction, one librarian explained that "some books are interactive. We see animals jump out of the page…books that really want the kids to come into the books and also the characters to go out." The participants repeatedly emphasized the storytelling aspect of the design task and in the representation of objects in 3D.

Design Task Findings: During the entirety of the workshop, the librarians continuously brainstormed about opportunities for 3D printing in their libraries beyond tactile books, including 1) creating open-ended toys (additive toys where evolving experiences and scenarios allow the child to be the instigator); 2) creating interactive wall installations and shadow puppetry; and 3) developing a prompt for local authors to produce original work paired with 3D model illustrations in association with National Novel Writing Month in November.

As we described and explored the tactile graphics guidelines, the librarians explained how illustrations were carefully composed to tell an important part of the story, and how original artistic choices were essential to the narrative. One participant was very interested in, "thinking about how to maintain the integrity of the original work; the pictures are not just illustrating the story, they are telling the story." For example, the librarians explained that in the case of Where the Wild Things Are, as the main character becomes increasingly engrossed in the world of the Wild Things, the images increase in size. Another librarian pointed out how some illustrations make readers interact with the book in different ways. In some instances, book illustrations require one to turn the book's page to become part of the story environment. Other book illustrations focus on engaging readers in their immediate surroundings.

Throughout the modeling work, the group paused multiple times to discuss the key challenges and advantages of using 3D printing as a medium for approaching the design task. They were engaged with the materiality of the books as well as the content, deliberating on how to transcribe a detailed picture while simplifying it for printing. The librarians referred to the decoding and abstraction of the images and discussed the advantage of graphic novels in the balance between graphical simplicity and conveying concepts. Size optimization was also taken into consideration as they considered both printer limitations and the fact that larger formats are

more accessible for younger tactile learners. Finally, 3D printing was suggested as an activity to engage parents in storytelling. One librarian said that “the material act of transcribing the book would help a sighted parent think about her child’s experience.”

Modeling Task Findings: Participants began modeling individually, but eventually decided to work in pairs. At the end of the workshop, the group gathered to focus on modeling a "package" of models that could be used in different configurations to represent different concepts in a book. In doing so, they explored how some stories are not linear and that moving parts may provide a richer experience. While modeling in TinkerCad, participants had difficulty distinguishing between icons for re-scaling objects and moving them vertically in space. They exhibited a lack of knowledge about the use of navigation tools to orient their work in space and had difficulty learning the techniques of the 3D modeling environment, such as re-orienting objects from different angles. Finally, there was some confusion about the effects of grouping objects and how to select multiple objects at once. When the librarians encountered a problem with the software, they verbalized the challenge, and the group often discussed solutions collectively. Most participants left with a sense of gratitude while acknowledging that more practice would be needed with the program to achieve the design task, although they were more inclined to help with future book selection and activity creation efforts than model design.

Talking Book Library Volunteers

Overview: Seven volunteers from the Colorado Talking Book Library attended this workshop, which was organized by the director of the library (similar to 5.1). All participants were retirees, who collectively had years of experience in contributing to the library’s effort to translate books into an audio format. The director of the library strategically recruited these

volunteers for the workshop because of their long-term contribution to the library, and their perceived abilities and interests in technology in general.

Prior Experience: While none of the volunteers had experience with 3D printing, three had used 3D modeling programs, and several others had extensive experience with audio recording and transcription technology. All of the participants interacted with blind patrons at the library. One of the participants had a blind spouse, while another referenced his children and grandchildren's experiences using 3D printers as his motivation for attending the workshop, and the others attended to help support the library.

Workshop Adaptations: We challenged participants to select images from Goodnight Moon and find a model on Thingiverse that they thought would be accessible through touch to focus the group conversations about transcription onto a concrete task. When working in TinkerCad, we focused on participants' efforts to navigate the screen and move forms.

Design Task Findings: The volunteers focused much of their conversation on the strategies used at the library to make content accessible. They spent little time critiquing the pre-fabricated models but discussed how audio-transcription guidelines might be used to help with visual-to-tactile transcriptions. During the overview of the 3D modeling software, the library volunteers focused on the applications of 3D modeling; they were most concerned with how people use different types of media but were reluctant to go deeply into the design process and consider how to transcribe the materials.

Modeling Task Findings: To engage the participants in the design process, we opted to spend more time walking them through the 3D modeling and printing ecosystem and helping them set up accounts on Thingiverse and TinkerCad. This process took nearly an hour. Several people were worried about setting up accounts, and one participant sent an email after the

workshop saying, "I resent having to set up an account with the CAD software...it was a great experience - just not my "cup of tea" for in-depth participation." Another repeatedly said that "I cannot do this, I am not good with the computer." When using TinkerCad, all participants had difficulty distinguishing between the icons for scaling and moving an object in space. One participant could not understand why objects “got bigger” as they moved across the page, and despite attempts to explain the idea of perspective within the software (closer objects appear larger), they ignored suggestions to rotate the page to a bird’s-eye view for more intuitive object behavior. Compared to other groups, this group received the most guidance due to frustration with the software.

Engineers

Overview: After a local hacker/maker space learned of our research, they offered to run a workshop for their members. Three hackers responded to the invitation, and all identified themselves as engineers. Due to the small group size, we observed each participants' work as opposed to as a group.

Prior Experience: The three engineers had greatly varying familiarity and comfort with 3D modeling. The most confident modeler (Participant A) worked with SolidWorks on a daily basis as part of his job designing medical tools. Participant B was identified as a 3D modeling hobbyist and was most comfortable working in Sketch-Up. Participant C indicated that he had used a 3D modeling program once or twice before. All three participants were motivated to join the workshop due to previous experience living or working with people with VI or cognitive disabilities. They all expressed interest in contributing to efforts that led to equal access, though none of them had previously made ATGs or ATPs. At the beginning of the workshop, each person shared their personal experiences with friends and family members who have VI.

Workshop Adaptations: The introduction and technology overview were cut short due to Participant A and B's eagerness to start using the modeling software and work independently. In turn, we spent a considerable amount of time helping Participant C become familiar with TinkerCad.

Design Task Findings: Despite the range of technical experience, all three participants' design processes and decision-making were heavily mediated through the 3D modeling tools they used. Participant A quickly chose to design pieces of fruit from the book Each Peach Pear Plum and focused on creating an exact representation of the fruit. Several times through the session he discussed the challenges of modeling, as opposed to focusing on the challenge of transcribing the images. He explained that "the reality of it is any parent with a disabled child is not going to have the time to sit and model unless they do that for a living."

Participant B brought in a book to model from and had been practicing using SketchUp in preparation for the workshop. He had decided on a strategy for completing the design task beforehand by scanning images of the book to import into SketchUp. The Giving Tree was one of his favorite books. "I want to convey the relationship between the boy (who becomes a man) and the tree. It is about love, the environment, and time." When describing his design process, he said that "the story did not need to be told page-for-page. As long as the message gets conveyed, I feel the volume of content printed is unimportant." While not focusing on decoding, specifically, it was evident that he was thinking about the way content was portrayed, how to simplify difficult concepts into more basic representations.

After facing difficulty with the learning the 3D modeling programs, Participant C eventually chose to represent three bears sitting on chairs from Goodnight Moon. He first created a storyboard to distill the concepts of the book and chose to focus on the concept of bears sitting

on chairs. Of all the participants, he focused on the particular learning purpose of the model the most.

Modeling Task Findings: During the modeling work there was very little dialogue between participants; one elected to put on headphones. However, when prompted, all were happy to help each other problem-solve while modeling. Participant A focused much of his time on identifying how to use the 3D modeling tool most efficiently to achieve the task. By using various geometric line tools alongside the extrusion tool, he was able to 3D model a pear and an extruded an apple. He focused on making sure edges were rounded due to his concern about the feeling of the plastic on a child's finger. It was evident that he was learning through trial and error, and by the end, his models of the illustrated fruit closely represented the images portrayed in the book.

Similar to Participant A, Participant B focused his modeling on how to leverage the efficiency of using SketchUp to transcribe an image. Using the rescanned images of the book, he used the freehand tool to define the shape of his model. He used the copy/paste tool to render the many leaves on the tree before extruding them all at once. Due to difficulties with downloading and loading SketchUp and creating an online account for TinkerCad, Participant C began modeling with clay. When referencing the 3D modeling program, he said, "I thought it would be a simple thing—I'd just start a project, and it'd just be flowing, and it suddenly is not… I am feeling very frustrated." Despite the differing modeling styles, each participant was innovative in their solutions (whether switching media or using different modeling methods), and was proud of their final representations.

Interaction Designers

Overview: Four interaction designers with experience with educational technologies and material design participated in a workshop. They learned about the research through a colleague and wanted to engage in a making task that had social implications while learning more technical skills.

Prior Experience: Three participants had never used a 3D modeling application, while the fourth had extensive modeling experience with Maya. Of all of them, only one had used a 3D printer. The three inexperienced participants chose SketchUp because it provided an option to use the mouse to draw lines and irregular shapes, while the experienced participant chose Maya. None of the participants had experience spending time with children with VI, but two had young children and were motivated to participate in exploring the use of tactile pictures in their homes.

Workshop Adaptations: After initial introduction activities, we worked more in-depth with this group to develop modeling skills. All participants had 3D modeling programs preinstalled on their computers. The Maya user was eager to start modeling and urged others to use their experiences to inform their ideas.

Design Task Findings: Several participants brought in their favorite children's books, but the group opted to work together to complete one book, Mommy Loves, because they were concerned about the time it would take to complete the design task. They divided the pages up, defined a template for the page size, and collectively decided where to put text on the page. They all worked independently and remained focused on the task until the end of the workshop.

While working, the group continuously provided suggestions for how to achieve the design task, such as how to break the design task down into simpler parts by dividing up the tasks by specialty. One commented that "the most effective approach to designing a tactile page

is not by giving the whole task to a 3D modeler initially, but to design with other materials…to identify key characteristics of the book, and then passing that off to a modeler.” When asked whether they were interested in learning more about designing for people with VI, one responded, "Even with professional experience with modeling animations with Maya, and I realize that this field is huge and requires depth/professional efforts in it." Many of the group's design process and design-based decisions focused on how to manage the task.

Modeling Task Findings: The participants using SketchUp immediately became frustrated by the unintuitive nature of the icons and the "unexpected" behavior of navigation. However, they tried to work through their problems by finding alternatives. For instance, when one participant struggled to model something that looked like the illustration, they elected to take a picture of the illustration and import it into SketchUp to trace over. After this, each participant opted to work with the freehand drawing tool to transcribe a two-dimensional representation of an animal, followed by using the extrusion tool for the 3D representation. All participants found the freehand tool frustrating due to the lack of control when using the mice as a pen or brush. Participants also found it difficult to close these free-drawn lines because the point of origin was difficult to distinguish. Participants were dissatisfied with the hard edges from using the extrusion tools.

Two of the participants lost motivation to complete the task due to the seemingly insurmountable barriers presented by the technology. “I realized the limitations and frustrations in technology as part of the creative process...even learning the options for how to maneuver were not intuitive!” This participant also had experience in sculpting and was more accustomed to using her hands to produce work. By the end, all four participants produced a model of a unique page in the book.

Figure 3.3. Examples of Workshop Groups' Models. (From left to right) Accessibility Librarians, Children's Librarians, Engineers, Interaction Designers, O&M/TVIs. (Volunteers did not produce any models).

O&M Specialists and TVIs

Group Overview: Forty orientation and mobility (O&M) specialists and teachers of the visually impaired (TVIs) participated in a workshop conducted in conjunction with a Department of Education (DoE) teacher training workshop. The coordinator for the training requested the workshop after receiving requests from teachers to learn more about 3D printing.

Prior Experience: All of the participants had experience making ATGs and teaching K-12 students with VI. Only one person in the crowd had used 3D modeling software and 3D printers.

Workshop Adaptations: The DoE coordinator asked to have a demonstration on how to use 3D modeling programs to transcribe images of road intersections since various types of intersections that can make wayfinding difficult for older students. While this task and modeling work focused more on the design of 3D-ATG maps than the design of 3DP-ATPs for emergent literacy, we chose to include these findings because much of the discussion-based data we collected pertained to 3DP-ATP. During the introductory activities, we created a 3D modeled tactile intersection template and showed the participants how to construct a basic intersection based on a picture. We then presented pre-fabricated 3D printed tactile copies of Good Night

Moon and prompted the participants to critique it. The group elected to break up into teams of four to model using SketchUp.

Design Task Findings: While working in small groups, many of the participants began by sharing ideas on how to use 3D printers. One person noted that “tactile pictures with raised lines could be great for tactile coloring books, not for rendering concepts like background and foreground.” Another person was thrilled by the possibility of making a replacement for a special tactile book she used with a student. “I have searched and searched for this grommet-shaped part for my book…I cannot believe how much time this will save.”

While examining the pre-fabricated 3D printed tactile picture books, many people referenced known guidelines. “Be aware of the amount of space you are putting around the objects. It is difficult to feel small objects on a flat space when you are not aware of the story being told." They indicated that it is important to design materials to complement the child's immediate environment/routines, with a particular focus on basic experiential concepts, spatial relationships of objects on the page, and a progression of materials and activities that help develop finer tactile acuity. One person said, "The most important thing is to keep the models simple and make sure that you work with the student to make sure they find the tactile picture makes sense to them. People learn to make sense of what is around them. Don't assume when you introduce a new tactile it will immediately make sense.” Throughout the workshop, many of the O&M and TVIs advocated for involving children with VI to evaluate whether the models were accessible. “Get more blind people involved with testing the models and graphics because they will be able to provide more useful feedback than a sighted person because they are more informed about what they need.”

Modeling Task Findings: In almost all groups, one person became the lead modeler, while others observed, discussed, and gave advice regarding their work. Those who spent the majority of their time modeling focused on learning how to make simple shapes and to navigate the modeling environment. They expressed frustrated with not knowing where to find the design tools within the menus. One modeler expressed hesitation about the technology, saying "maybe I am interested in 3D printing for tactile graphics in a progressive kind of way, but for our district, it is not practical right now...it needs to become easier." We heard this time and time again. No team produced a complete model.

Still, the majority of the O&Ms and TVIs remained positive about 3D modeling and printing technology. One person reflected that she could now create something she had been trying to find for years. Another said, “I just can’t wait to learn how to apply this technology, and visualize all the possibilities.” However, there was a generational divide between those interested in 3D modeling and related software, and those who felt that it was too complicated. One participant commented, “I am about to retire. This technology is for the next generation to pursue.” Many teachers discussed available time being a deterrent to learning how to model, along with the lack of resources and time to participate in technology workshops.

Table 3.1. Findings by Workshop Group

A	B	C	D	E
Group	N=#	Knowledge	Design Thinking Focus	Design Task Requirements
Accessibility Librarians	7	Media Access and Distribution	• Focused on use of existing guidelines • Focused on understand theoretical • implications of transcription	• Include/honor skills of people with VI • Choose relevant (time/context) • representations of information
Childrens Librarians	6	Emergent Literacy	• Focused on individual learning needs • Focused on task management, community support and	• Design simple features around a concept • Consider artists’ original work

			collaboration	
Library Volunteers	7	Audio Transcription	• Focused on novelty of the technology • Focused on how to facilitate end use	• Consider the use of audio formats to complement the 3DP-ATP
Interaction Designers	4	Design and Engineering	• Focused on efficiency of modeling • Focused on complexity of modeling	• Have a realistic view of the work • Focus on the book's learning goals
Engineers	3	Interaction Design	• Focused on management of design task • Focused on defining new design methods	• Create templates to increase efficiency • Parse the design task according to abilities
O&M/ TVI	40	Vision Sciences	• ·Focused on adhering to guidelines	• Understand the child's learning context • Include VI people in the evaluation

Findings: Across Groups

Above we summarized how each participant group approached the design task. Here we observe which aspects of the task they focused on and the associated design requirements. We note that participants approached the work according to different roles.

Designer Roles

Each group that we worked with focused on different aspects of the design task and revealed a series of requirements for creating 3DP-ATPs. Among the 67 participants, four primary ways of approaching the task surfaced. Some participants focused on developing materials to support individual needs, some focused on the creation of guidelines, while others focused on the theoretical implications. We identify these roles as:

1) End-User Advocate: During our workshops, those who work with people with VI on a regular basis (O&M specialists, TVIs, and Accessibility Librarians) strongly advocated for designing content that is both specific to individual children while adaptable to suit other children's needs. They emphasized the importance of knowing the child's cognitive ability and VI before modeling. These participants also designed, referenced and applied existing guidelines for ATGs/ATPs, indicating that this is standard practice within the profession. In cases that they were not aware of existing ATG guidelines, they attempted to create their own, exhibiting an understanding of how to scaffold a VI child's learning by describing specific model characteristics and identifying the appropriate levels of storytelling.

2) Content Translator: The early childhood librarians and accessibility librarians displayed an ability to apply their knowledge on emergent literacy, exhibiting a range of skills necessary for unpacking and abstracting content, and advocating for artistic, intellectual property rights. They approached the task with a strong focus on how to decode visual illustrations and the meaning they convey. They emphasized how the composition of elements on a page created a graphic narrative and concentrated on discussing the phenomenological aspects of transcribing across the senses. These participants also placed a higher value on whether or not authors' original intent and artwork are fairly represented, and made recommendations for how to look at the whole of the stories and decode certain elements, a value we did not observe in other groups. They also valued how material artifacts are used appropriately to engage children in meaningful ways, and how materials can be used to support joint attention (for emergent literacy). Most recognized that in some instances 3DP-ATPs might not convey the totality of the original author or illustrator's intent. Some trade-offs must be considered.

3) Task Manager: The librarians also showed strong organizational skills around task management and book selection, which enabled them to quickly select and analyze the structure and components of the book, and communicate about important aspects of the transcription task. They emphasized the consideration of original artists' work and design communication (the concept, sequencing, and interactivity) efforts, in turn weighing the trade-offs between simplifying graphics and staying faithful to the original illustrations. They also recommended blending media to make the most appropriate representation of the information. The interaction designers exhibited similar organizational and management ability. However, they tended to look at the entire scope of the of the design task, in turn parsing out different aspects of the work to different collaborators. They exhibited a meta-level review of the design task while modeling.

4) Modeler: The participants with previous modeling and design experience (engineers and interaction designers) showed the ability to problem-solve within the 3D modeling environments. They wanted to start by modeling with tools and discuss their approach/challenges/successes with the design task in progress, as opposed to the less technically experienced participants who spent more time analyzing the task before trying the programs. They tended to focus on how information was communicated through form, but not specifically on how to make the information accessible. They quickly identified the complexity of the design task and made recommendations for how to improve efficiency while modeling, and how to scope and manage the work.

Underlying Skill Sets

As described above, after all of the workshops concluded, we ranked each participant group's dominant skill sets according to five criteria to further evaluate and summarize the strengths of each participant group: (1) Human development, (2) Emergent Literacy, (3) Tactile

Graphicacy, (4) Task Management, and (5) Modeling. No single group has skill sets across all five categories. Each workshop group that elected to participate in this study (except for the volunteers) showed strength in two or three skill sets, for example, the TVI's (4.6) showed strength in demonstrating and applying knowledge about human development and tactile graphicacy during their design work. Each workshop group had different coupling of skills. These findings have implications for future work, as discussed in the next section.

Table 3.2. Skillsets by Workshop; D= Human Development, L= Literacy, G= Graphicacy, T= Task Management, M= Modeling

Group	D	L	G	T	M
Accessibility Librarians	3	3	2	2	2
Childrens Librarians	2	3	3	3	2
Library Volunteers	2	1	1	1	1
Interaction Designers	1	1	2	1	3
Engineers	1	2	2	3	3
O&M/ TVI	3	2	3	2	1

Discussion and Future Work

The space of designing ATGs and ATPs has existed for some time, but using 3D fabrication tools to create and design these materials is still a new field. To the best of our knowledge, no other study has systematically reported on how non-professional modelers, transcriptionists, and tactile artists use personal fabrication technology to create 3DP-ATPs. During our participant recruitment, it became apparent that TVI's and O&M specialists, librarians, interaction designers, engineers, and other volunteers, with varying skill sets, are interested in creating 3D-ATPs for children with VI. Some of the 67 participants joined the workshops due to a personal connection with somebody who is blind. Some joined as a way to

increase their exposure to emerging technology, and others joined merely to contribute their skills to a meaningful cause.

We designed the workshops to introduce participants to the task and to mitigate the known barriers to designing 3DP-ATPs for the first time. Depending on their experience we provided overviews and hands-on instruction of 3D modeling programs, examples of ATGs, ATG guidelines, sudden blindness experiences, lessons in decoding and abstraction, etc. Each of the groups approached the task of creating 3DP-ATPs from a different perspective. We identified the dominant focuses in each group's design thinking, e.g., Accessibility Librarians= Focused on use of existing guidelines, and focused on understanding theoretical implications of transcription**.** Each participant group's design thinking focuses and associated requirements indicate that people elect to take on a specific role in the design process: End-User Advocate, Content Translator, Task Manager, or Modeler.

Nonetheless, we noted that designing from just one of these roles or perspectives did not prove to produce a meaningful 3DP-ATP; 3DP-ATPs produced by a person with exposure to only one or two skill sets may fail to make a 3DP-ATP that tacitly communicate what is essential to a child's learning. Despite our efforts to mitigate the challenges of creating 3DP-ATPs, many of the caregiver and stakeholder groups did not innately recognize the full scope of what is required by the design task or know how to apply existing ATG guidelines and tended to stay within their domain-based comfort zones. Their experience begs the question of whether 3D modeling and printing can be successfully leveraged by caregivers and stakeholders, who often have limited time and resources to learn new skills, for the creation of ATPs and ATGs? We believe that caregivers and stakeholders have critical knowledge to contribute to the design task, and given the right resources will be able to create 3DP-ATPs. However, this will require

making the design task more approachable to amateur makers and leveraging caregivers and stakeholders existing skill sets and motivations for creating meaningful 3DP-ATPs.

Design Activities and Associated Roles

Participants offered valuable advice on how to make the design task more approachable. Their recommendations fall into four different categories that parse the task into activities. Each of the activities corresponds to one of the four key design roles caregivers and stakeholders are prone to take on while approaching the task.

Activity A- Need Assessment and Evaluation: Understand the child's learning context at the onset of the design process and include people with VI in the evaluation of the models. → End-User Advocates' skills can be used to validate printable tactile pictures modeled by others for composition and tactile detail, to identify 3DP-ATP projects for specific children, and to coordinate the inclusion of end-users and caregivers in the evaluation.

Activity B- Content Selection: When selecting content to translate, consider the meaning associated with the artists' original work, choose books according to the intended learning goals, and consider the use of audio formats to complement the 3DP-ATP. → Content Translators' skills can be used to help select books, identify the project scope with initiators, and edit content to enhance how designs are communicated across the senses.

Activity C- Representation: When designing content, choose relevant (time/context) representations of information and design simple features around a single concept. → Task Managers' skills can be used to help determine the sequences in which design activities should occur in the process of creating a 3DP-ATP, and to provide assistance and explicit instruction to each of the other team members— mainly the modelers.

Activity D- Production: When creating models, begin with a realistic view of the work and possibly divide the design task according to abilities, and create templates to increase efficiency. → Modelers' Skills can be used to develop guidelines and easily replicable samples of work, along with the task manager to engage in the design cycle with the others.

Collaborative Design Platform

The recommendations above for parsing the design task and ways using one's skill to contribute to the creation of 3DP-ATPs can be used to inform how participants interact while collaborating to create 3DP-ATPs. However, similar to the existing ATG guidelines, this information alone may not adequately prepare caregivers and stakeholders to contribute their skillsets collaboratively. In turn, we propose the design of a digital fabrication tool to unite designers from different disciplines around 3DP-ATP projects, while providing individuals to use their skills to make meaningful 3DP-ATPs.

This future research task treats the design of 3D-printed ATPs as a collaborative, transferrable process inclusive of a broad range of stakeholders including parents, teachers of the visually impaired (TVIs), librarians, and other community volunteers. Based on the findings of this study, we anticipate that an online, 3DP-ATP collaborative design platform may include features that enable people to 1) build teams of designers; 2) propose design projects; 3) notify participants of project activities; 3) visualize progress and task allocation; 4) support communication between different team members; and 5) scaffold designers learning about ATG and ATP guidelines. We anticipate that a tool of this nature will require community management, and will look to the literature on social computing and creativity support tools to inform future designs. From the findings presented in this research, we anticipate that children's

librarians and TVIs would be the early adopters to rally other community members to help make 3DP

We plan to run additional workshops to help form multi-disciplinary teams of participants representing each of the identified roles. This research will aim to identify how the team members collaboratively approach the task, whether multi-disciplinary teams disrupt the notions of the roles, we present here, and what unique interface features will support their synchronous and asynchronous collaboration. To date we have not encountered teams of 3DP-ATP designers in the wild, however many caregivers identify the need for more shared resources on the design of accessible 3D material. We hope through the creation of such a tool will enable such a community to emerge.

Conclusion

In this paper, we presented insight into how six groups of stakeholders of children with VI approach the design task of 3D modeling accessible tactile pictures. Workshop participants demonstrated that the design task requires five different skill sets: disability science, literacy, graphicacy, project management, and 3D modeling. Of the 67 research participants we worked with, no one exhibited all skillsets. However, we identified that participants typically approached the design task from one of four roles: end-user advocate, content translator, task manager, or modeler. Each participant group specified requirements for approaching the design task from these associated roles, which we used to establish a framework for how caregivers and stakeholders can collaboratively design 3DP-ATPs. Future work will focus on assessing how multidisciplinary teams approach the work and how to develop creativity support tools to involve various stakeholders, and how to develop a collaborative design platform for the creation of 3DP-ATPs.

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CHAPTER 4:

CONSUMING AND PRODUCING TACTILE MEDIA FOR AND WITH PEOPLE WHO ARE BLIND AND VISUALLY IMPAIRED: DEFINING PROBLEMS OF PRACTICES TO ADVANCE THE FIELD OF TACTILE MEDIA STUDIES

Prelude

The research I present in this Chapter deviates slightly from the focus of the prior two chapters: where the research presented in those chapters leveraged teachers', parents' and caregivers', and other community stakeholders' interest in the application of 3D printing to create tactile pictures to investigate their familiarity in tactile learning media for students (Chapter 2) and perspectives on tactile media design, in Chapter 4 I no longer leveraged 3D printing as a tool to organize user-centered research. By this stage of my Ph.D. research, I was connected with a broader community of tactile media consumers and designers and did not need to leverage my research lab's growing expertise in 3D printing as a way to recruit participants. However, like the research presented in the previous two studies, the research I present in Chapter 4 is similarly focused on building new understanding about invested stakeholders' engagement with tactile media.

The chapter presents a qualitative study that was conducted over the course of two years (2016 and 2017) in collaboration with the National Federation of the Blind (NFB) and tactile artist Ann Cunningham, and supported through the Build a Better Book project.

In early 2016, I joined Cunningham in meetings with the NFB to devise avenues through which people who are BVI might become more exposed to tactile media—both art and graphics. The opportunity to participate in these meetings represented a forum through which I could build

upon and share my knowledge about tactile media design. In time, the objective of these meetings solidified. Based on Cunningham's vision, we decided to design and implement three events where invested practitioners could gather and discuss the state of tactile art and graphics in education and other professional and personal pursuits. I quickly came to see the "Tactile Arts and Graphics Symposia" (TAGS) as a rich context to identify the underlying problems of practice that pose barriers to blind and visually impaired (BVI) people's access to tactile media as well as the accessibility of different forms of tactile media and art more generally.

I believe that the findings from this study will directly contribute to the TAGS participants who invested their time and energy in the events. Further, the findings contribute to the broader community of people interested in developing socio-technical systems and interventions to improve BVI people's access to tactile media and accessible art experiences, to position people who are BVI as producers of artistic and informational media, and to reduce the stigma of touch for all media consumers and producers. Accordingly, I have written this paper with the hope of publishing an amended version of it to the ACM Transactions on Accessible Computing, a quarterly journal that publishes refereed articles addressing issues of computing as it impacts the lives of people with disabilities. It provides a technical forum for disseminating innovative research that covers either applications of computing and information technologies to provide assistive systems to persons with disabilities or investigations of computing technologies and their use by persons with disabilities.

Introduction and Background

Over the past forty years, the human-computer interaction (HCI) community has been working to devise technical and socio-technical solutions to address what Buxton (1986) called a "gap between computer accessibility by disabled and nondisabled populations," which

"appears to be widening rather than narrowing" (Buxton, Foulds, Rosen, Scadden, & Shein, 1986, p. 293). While there are many gaps to be filled in relation to the design and development of accessible systems and interfaces, a persistent gap that we focus on in this paper is the need to develop information systems that create tactile learning experiences and access to visual information for people who are blind and visually impaired (BVI).

The need to develop information systems that create tactile learning experiences and access to visual information is not a new problem. But the gap has not yet been narrowed sufficiently.

Computer scientists and mechanical engineers have been developing interfaces to make graphical information accessible through the sense of touch for quite some time. Bliss et al (1970), for example, created a system to produce a tactile image through a 24-by-6 array of pins driven by piezoelectric bimorphs in 1970 (Bliss, Katcher, Rogers, & Shepard, 1970). Others have focused on developing systems to automate visual to tactile translation e.g. (Way & Barner, 1997a, 1997b) and preparing tactile graphics designs for production using Braille printers, e.g. (Batusic & Urban, 2002).

Many of these early efforts focused on the technical challenges of developing such systems. In 2005, Richard Ladner conducted one of the first user-centered studies to investigate the design practices of people involved in the design of tactile graphics that represent information (e.g., bar charts, diagrams, line graphs, etc.) and developed an interface that automated the design process to increase the supply of tactile graphics (Ladner et al., 2005). In more recent years, scholars in the human-centered computing (HCI) and access computing (ASSETS) research communities have focused on creating accessible graphics through leveraging and developing new tactile production technologies e.g. (Brown & Hurst, 2012; Shi,

Zhao, & Azenkot, 2017) as well as developing dynamic tactile displays e.g. (Guinness, Szafir, & Kane, 2017; Suzuki, Stangl, Gross, & Yeh, 2017).

Many of the aforementioned systems and research efforts have focused on the production of tactile graphics as opposed to other forms of tactile media. Whereas tactile graphics are representations of data and information made up of raised lines, areas, textures and symbols and are the primary means by which blind people access maps, graphs, diagrams and other graphical representations (Aldrich 2008, page 1), there are other types of graphical medium—pictures, illustrations, sculptures, multimodal compositions—that are important for a person who is blind or visually impaired to access through the sense of touch.

Responding to this gap, the HCI and ASSETS community has started in recent years to investigate the opportunities to develop technologies and interfaces to produce tactile illustrations and pictures, e.g. (Cantoni et al., 2018; Kim & Yeh, 2015; Stangl, Hsu, & Yeh, 2015), as well as how access technologies can make artistic content accessible through touch and multimodal experiences (Cavazos Quero et al., 2018; Kyle, Salmon, Thornton, & Joshi, 2017; Reichinger, Maierhofer, & Purgathofer, 2011). In a recent study, Asakawa et al. (2018) conducted the first HCI-focused study to understanding the opinions and expectations that people who are BVI have when visiting museums (Asakawa, Guerreiro, Ahmetovic, Kitani, & Asakawa, 2018). Central to many of these research efforts is the understanding that access to concepts portrayed through visual art and all forms of tactile media—graphics and maps, pictures and illustrations, and art—is important to BVI's full inclusion in social life and participation in personal and professional pursuits.

Despite the success of these efforts, many people who are BVI are still not positioned and prepared to consume data and other culturally important media and information through the

sense of touch. Similarly, many people who are BVI have not been positioned or prepared to fully participate in the creation of media and information. Accordingly, we began to wonder about the broader problems of practice faced by people who are BVI as they engage in the consumption and production of tactile media—graphics and maps, illustrations and pictures, art—and other forms of art. A problem of practice is "a persistent, contextualized, and specific issue embedded in the work of a practitioner, the addressing of which has the potential to result in improved understanding, experience, and outcomes" (Perry, 2016). Problems of practice are not usually based on individual cases but involve a group of people or a particular population, and are generally identified through reflection on practice, dialogue with colleagues, and looking at the quantitative and qualitative-based research literature on the topic (City, Elizabeth A, Elmore, Fiarman, & Teitel, 2009; Osterman & Kottkamp, 2004).

In this paper, we therefore present a qualitative study to identify the contemporary factors and issues that create barriers to BVI social inclusion, or "full participation in all aspects of life" (Department of Economic and Social Affairs, 2009, p. 12) as experienced by people who are BVI who are actively involved with tactile media consumption, production, and instruction. Specifically, we address three research questions:

1. What are the factors/issues that impact the art and graphics consumption, production, and instruction, practices of participants who attended the Tactile Arts and Graphics Symposia (TAGS)?
2. What strategies do the TAGS participants identify as contributing to or inhibiting access and participation?
3. What do the factors/issues and strategies reveal about the problems of practice related to tactile media that the TAGS participants and in turn similar stakeholders encounter?

To address these questions, we conducted a qualitative study, guided by (Strauss & Corbin, 1994), of data collected during the implementation of three social learning (Bandura, 1977) experiences, named the Tactile Art and Graphics Symposia (TAGS). The TAGS were sponsored by the National Federation of the Blind (NFB) and held in December 2016 in Baltimore, Maryland; May 2017 in Boulder, Colorado; and September 2017 in Napa, California. We designed and implemented the TAGS based on our experience—as sighted and visually impaired tactile media practitioners and scholars—that people do not engage in media and information practices (crafting, designing, producing, consuming, and instructing) in isolation. For each of the TAGS events, we brought together approximately 30 people—BVI and sighted—working as access technologists, disability and blindness advocates, artists, art educators, designers, engineers, museum curators, rehabilitation educators, and researchers to discuss the state of tactile media creation, production, and instruction based on their lived experiences.

Our analysis the data resulted in the identification of five core problems of practice: 1) Belonging and Conspicuousness; 2) Touch as Deviance; 3) Inadequate Educational Programming; 4) Nascency in Tactile Design and Representation; 5) Access To vs. Accessibility Of. Through our investigation of the contemporary and lived issues that impact BVI people's art and graphics consumption and production practices, and our identification of the underlying problems of practice, we provide people the ASSETS community with new approaches and strategies to develop accessible media experiences and practices.

Study Design

The research questions[22] guiding this study emerged when Lou Ann Blake, Ann Cunningham and I gathered around the idea of creating an event focused on tactile art and tactile graphics. During our initial planning meetings, we found a sense of mutualism based on two shared observations:

A. People who are BVI consistently encounter barriers that limit their opportunities to consume and create/produce art and graphics.
B. There are no forums where practitioners and scholars who consume, produce, and instruct with tactile media can come together and discuss the issues that impact their practices, compare experiences, and envision solutions.

These two mutually defined objectives guided the design of the TAGS and iterative evaluation of the procedures we used to during each events implementation, as well as the formation of a Research Practice Partnerships (RPP) to formally investigate the aforementioned research questions. RPPs are collaborations where practitioners and researchers join forces to investigate and address problems of practice—in formal (Coburn, Penuel, & Geil, 2013; Penuel, Fishman, Haugan Cheng, & Sabelli, 2011) and informal (Bevan, 2015) learning environments—through the original analysis of data collected during interventions (Coburn et al., 2013).

In the case of this research, the RPP team members include: an information experience design researcher at a US-based university who was interested in identifying issues affecting people involved in tactile media design and supporting the formation of a community of practice

[22] The research questions guiding this study include: 1) What are the factors/issues that impact the art and graphics consumption, production, and instruction, practices of participants who attended the Tactile Arts and Graphics Symposia (TAGS)?; 2) What strategies do the TAGS participants identify as contributing to or inhibiting access and participation?; 3) What do the factors/issues and strategies reveal about the problems of practice related to tactile media that the TAGS participants and in turn similar stakeholders encounter?

focused on tactile media creation; a practicing tactile artist and art educator of BVI individuals who wanted to gather thought leaders and practitioners who consume and produce tactile art and create an experience where participants could touch the same objects and compare their tactile experiences in situ; and a tactile art advocate and representative from the NFB, who, along with her colleagues at the national advocacy organization, considers the appreciation for and enjoyment of art as part of "living the life we want." One of us has low vision. Two of us are sighted individuals.

Methods

Setting and Recruitment

The settings, and recruitment procedures, for the three TAGS differed, as described here.

TAGS 1

To recruit participants for the first TAGS, we identified a pool of people who we knew to be actively engaged in creating and producing tactile materials, individuals concerned with the state of access to art and accessible graphics, and practitioners focused on teaching with tactile media. From the onset, we decided to limit the capacity of each event to 30 participants (including the RPP members) to ensure that the participants could get to know one another and engage in meaningful conversations. Furthermore, we strove to have an equal participation of BVI and sighted individuals (at least 50% of the attendees needed to be BVI), and agreed that the first event would target practitioners and scholars located in the East Coast of the United States and Europe as we were holding the first event in Baltimore, Maryland.

To identify an initial pool of participants, each of the RPP members identified people who met our basic criteria, and represented a diversity of perspectives, professions, and levels of

vision. We also chose not to invite vendors of tactile graphics production technologies so that the participants would not feel pressured to buy products or be influenced in other ways. We then consolidated our nominees into a final list and agreed on 25 individuals. The artist member and the NFB representative then collaboratively wrote the invitation and sent individual emails to the 25 invitees. The base invitation text read,

> "The National Federation of the Blind (NFB) considers appreciation for and enjoyment of art as part of living the life we want. To help break down the barriers that result from the stereotype that 'blind people don't do art,' the NFB is hosting a tactile art symposium, 'Putting More STEAM in STEM.' We are leveraging our existing expertise on how to teach blind students science, technology, engineering and mathematics skills and complementing that with exposure to art. This two-day event will gather together tactile artists, art museum curators, teachers of the blind and visually impaired, and blind students who are enthusiastic about art. The goal of this symposium is to create a community of supporters around tactile art through education and the sharing of resources. We also want to develop career paths that will open the doors to blind people to become tactile artists and tactile graphics providers."

Soon after the invitations were sent out, a wave of other practitioners and scholars contacted the NFB for an invitation. Before extending invitations to any of these correspondents, we sent an email to the initial 30 invitees asking for a response within the week. Subsequently we sent out additional invitations and accepted participants on a first come first serve basis until 30 spots were filled. In total we accepted 31 people. We allowed for one additional participant who approached us at the last minute to join the TAGS; she is BVI artist who worked at our host site.

The event was held in December 2016, over the course of two days in the Jacobus tenBroek Library in the NFB headquarters in Baltimore, Maryland. The Jacobus tenBroek Library contains the personal and professional collection of Jacobus tenBroek, the NFB Institutional Archives, and several smaller collections. The thirty-one TAGS participants gathered in a large circle of tables on the east side of the library, including three RPP members.

TAGS 2

Recruitment for the second TAGS occurred in much the same way as the first TAGS, except we focused our efforts on inviting practitioners and scholars from the central region of United States. We prioritized recruitment of first-time attendees, blind artists who facilitated the interactive sessions, and representatives from the Colorado Center for the Blind, an NFB affiliated independence training center.

The second TAGS was held in May 2017, at the National Center for Atmospheric Research (NCAR), a federally funded research and development center in Boulder, Colorado. The TAGS took place in the Mesa Lab, which consists of two adjacent rooms: one room functioned as the meeting room, and the other room served as the tactile art gallery. While 30 people committed to participating, only 25 people (including three RPP members) were able to make it to the event due to winter weather.

TAGS 3

Recruitment for the third TAGS occurred in much the same way as the first two TAGS, except that we focused our efforts on inviting practitioners and scholars from the western region of the United States. The LightHouse for the Blind and Visually Impaired hosted the third TAGS at their Enchanted Hills Camp located in Napa, California in September 2017. Large group discussions took place in a dining hall, small breakout group activities occurred in the “Hogan”

arts and crafts building and the Enchanted Hills Art Gallery, a room intentionally designed by George Wurtzel to display tactile art. Twenty-eight people (including the three RPP members) attended this event.

Participants

As indicated above, 31 people attended the first TAGS, 25 people attended the second TAGS, and 28 people attended the third TAGS. **Table 4.1** provides a breakdown of the people who attended the TAGS according to their vision and professional identity. Across all three events, just below 50% of the participants were BVI, either blind or low vision.

Table 4.1. TAGS Participant by Vision Level and Profession. (B=Blind, LV=Low Vision, S=Sighted, ST=Sub-total.

	Access Tech	Advocacy	Artist	Art Edu.	Designer	Museum Curator	Rehab. Edu.	Science Researcher	Social Researcher	Tech. Researcher	TVI Edu.	Total	%
TAGS 1													
B	1	3	3	0	2	0	0	1	0	1	0	11	35.4
LV	1	1	2	0	0	0	0	0	1	0	0	5	16.13
S	2	0	2	1	2	2	0	2	1	1	2	15	48.39
ST	4	4	7	1	4	2	0	3	2	2	2	31	100
TAGS 2													
B	0	0	3	0	1	0	2	0	0	0	0	6	24.00
LV	0	1	1	0	0	0	1	0	0	0	1	4	16.00
S	0	0	2	1	3	2	0	1	1	2	3	15	60.00
ST	0	1	6	1	4	2	3	1	1	2	4	25	100
TAGS 3													
B	1	1	4	0	1	0	1	0	1	2	0	11	39.29
LV	0	1	3	0	0	0	0	0	0	0	0	4	14.29
S	1	0	3	1	4	0	0	0	3	0	1	13	46.43

Table 4.1. TAGS Participant by Vision Level and Profession. (B=Blind, LV=Low Vision, S=Sighted, ST=Sub-total.													
ST	2	2	10	1	5	0	1	0	4	2	1	28	100.0
TOTALS													
B	2	4	10	0	4	0	3	1	1	3	0	28	33.33
LV	1	3	6	0	0	0	1	0	1	0	1	13	15.48
S	3	0	7	3	9	4	0	3	5	3	6	43	51.19

Several participants attended more than one of the TAGS events: the RPP members (whom we consider participants) attended all three events; two BVI artists attended all three TAGS; and five other people attended two events (**Table 4.2).** One participant did not consent to participate in the research. Thus there were a total of N=68 participants in our study.

Table 4.2. Return TAGS Participants				
Profession	Vision	TAGS 1	TAGS 2	TAGS 3
Access Tech Specialists	Blind	x		x
Advocacy (RPP Member)	Low Vision	x	x	x
Art Educator	Sighted		x	x
Artist	Blind	x		x
Artist	Blind	x	x	x
Artist	Blind	x	x	x
Artist	Blind		x	x
Artist	Low Vision		x	x
Artist (RPP Member)	Sighted	x	x	x
Designer	Blind	x	x	
Social Researcher (RPP Member)	Sighted	x	x	x
Technology Researcher	Blind	x		x
TVI Educator	Sighted	x		

To be included in the study, participants needed to be 18 years or older, available to attend the entirety of the event they were invited to, and be involved in the consumption, creation, or instruction of tactile media or educational experiences that involve tactile media.

Procedure and Data Collection

TAGS 1

Prior to the event, we notified the participants that the events would be recorded for research purposes; we obtained consent to record the emergent discourse following a procedure approved by an Institutional Review Board at the onset of each TAGS. All participants attending the first TAGS consented to be research participants. Participation in the event was not contingent on consent to the research.

Table 4.3 presents an overview of the sequence of events for each of the TAGS. TAGS 1 began at 9:00 am on Day 1 with a formal introduction from the NFB President Marc Riccobono and the RPP team members. All participants introduced themselves and their goal for attending the TAGS. We then commenced the first set of activities, which focused on tactile art consumption and lasted until 4:00 pm. All activities are described in the TAGS Event Design Overview section below. That evening, we held the Tactile Art Exhibit Opening. Fifty patrons from the community joined the TAGS participants in celebrating the exhibit, which was introduced by NFB President Riccobono. The second day of TAGS 1 commenced at 9:00 am with a discussion about the tactile art exhibit and strategies to make art more accessible. Subsequently, we led and moderated a series of activities focused on tactile graphics consumption and production. The first TAGS wrapped up with small group "Action Item" discussions and a large group conversation to identify strategies for the TAGS community to develop. We ended at 4:00 pm.

To collect data, I took field notes during the activities and placed three audio recorders around the rooms to capture the participants' conversations in the large and small group activities; as participants moved around the space, I adjusted the audio recorders appropriately. I

also placed three GoPros to around the room to later identify who was talking in the audio recording. I took field notes during the event.

Table 4.3. TAGS Sequence of Events		
TAGS 1	TAGS 2	TAGS 3
DAY 1 (Full Day)	**DAY 1 (Full Day)**	**DAY 1 (Afternoon)**
TAGS Introductions	TAGS Introductions	TAGS Introductions
Participant Introductions	Participant Introductions	Participant Introductions
Art Fitness 101 Activity and Discussion	Art Fitness 101 Activity and Discussion	Tactile Graphics Access and Reading Demonstration
Tactile Art Production Method Comparison Activity and Discussion	Accessible Art Museum Discussion	Tactile Graphic Reading Breakout Groups and Debrief
Art Fitness 101 Activity and Discussion	Tactile Art Exhibit Opening	
Tactile Art Exhibit Opening		
DAY 2 (Full Day)	**DAY 2 (Full Day)**	**DAY 2 (Full Day)**
Accessible Art Museum Discussion	Accessible Art Museum Discussion	Tactile Graphic Design Breakout Groups and Debrief
Tactile Map Demonstration	Tactile Graphic Reading Breakout Groups and Debrief	Inclusive Live Nude Modeling Sculpture Class Demonstration
Inclusive Tactile Graphic Design Activity and Discussion	Tactile Graphic Design Breakout Groups and Debrief	Tactile Art Creation Breakout Groups and Debrief
Tactile Map Design and Production Demonstration	Action Groups	Art Fitness 101 Activity and Discussion
Action Groups	TAGS Future Actions	Tactile Art Exhibit Opening
TAGS Future Actions		
		DAY 3 (Morning)
		Accessible Art Museum Discussion
		Accessible Art Museum Collections Demonstration
		Action Groups
		TAGS Future Actions

Immediately after the event, I listened to each of the audio files and identified segments for transcription. I used an audio file editing program to remove audio segments when nobody was talking, segments that were inaudible for transcription because too many people were talking or they were too far from the microphone, and segments of recordings captured outside of the scheduled activity time. Much of the data excluded from the analysis was captured during the small group breakout activities. The acoustics of the rooms in which the activities occurred was not optimal, especially when multiple small groups were working in the same vicinity as the recorder. For the first event, I sent approximately 8 hours of audio data to a professional, confidential transcription service. When I received the transcripts, I retroactively identified speakers indicated on the transcripts using the video data, and manually transcribed segments of the data that were skipped over by the professional transcription service.

I then used the field notes and the transcripts to create an outline of the chain of events that occurred during the first TAGS, as well as the major topics that emerged. When creating the chain of events, I began writing analytic memos regarding the different areas of concerns expressed by participants. However, I did not engage in a robust analysis of the data at the time (Please see the Retrospective Grounded Theory Analysis section below). Rather, I used the chain of events as a tool for reflection about the design and implementation of the first TAGS and to inform the design of future events. For future events, the RPP team choose to change the way the participants were positioned to engage in many of the activities. For example, the first TAGS included several rounds of the Art Fitness 101 Activity. The aim of running this activity twice was to scaffold participants engagement in the Art Fitness 101 questions. However, after implementing it we realized that running it a second time did not generate new conversations. In future events, we restructured this activity to only occur once and to take place in small groups.

TAGS 2

I performed the same consent protocol as TAGS 1. One participant did not consent to research. Their data were excluded during analysis and are not reported. I performed the same data collection protocol as TAGS 1, but the structure of the event differed slightly. The first event was scheduled to begin at 9:00 am but due to inclement weather began at 10:30. The first day's activities centered on tactile art consumption and then production. The day ended with the tactile art gallery opening at 5:00. The following day activities started at 9:00. After a debrief of the exhibit opening and how to make art accessible, participants engaged in a series of breakout group activities focused on tactile graphics consumption and production, with a discussion in between. Like the first TAGS, TAGS 2 ended with small group "Action Item" discussions, and a large group conversation to identify strategies for the TAGS community to develop. This ended at 4:00 pm. I performed the same data analysis procedure as reported for TAGS 1 above, for the TAGS 2 data. I sent approximately 6 hours of audio data to a professional, confidential transcription service.

Table 4.4. Examples of invivo Coding					
Context	Structural Code	Text Excerpt	invivo Code	Issue	Strategy
Participants introduction during TAGS 2	AC	Speaker 1: We're committed to always free admission. The admission of the Woodson Art Museum is to enhance lives through art and I think the museum has absolutely an atmosphere of inclusivity, accessibility and a very can-do attitude that's installed in all of us as staff members. I work with my fellow curator of education and we developed Art Beyond Sight, which is a program we offer during each changing exhibitions several times a year. In that program, we develop a multi-sensory gallery experience and some different tactiles and sound and storytelling, and verbal descriptions of artwork. We often work with guest artists. We've done soapstone carving, pyrography, clay, painting, woodworking. There's not an art form that we haven't tried and it's been really wonderful and rewarding.	creating an atmosphere of inclusivity		
Accessible Art “Action Items” Breakout Group share out during TAGS 3	AC	My husband and I had an experience like that at the Louvre, like three years ago. I had purchased the tickets ahead of time online. We get to the Louvre, and we're in line. We get to the person collecting the tickets and she's like, "Well you can get in for free, you don't have to pay." I'm like,	unwanted attention due to VI		

		"But we've already paid." And she's arguing with us. "No, no. You can get in for free. I'm like, "We've already paid! We want to support the museum. We're happy to do that"			
Defining Tactile Art Discussion during TAGS 1	AC	Each of us had pieces that resonated with us individually, and some of us had specific pieces that we reacted to individually. One of the things we talked about was abstract and concrete pieces, whether the meaning was conveyed non-visually and whether abstract art can be meaningful to blind people.	art interpretation	x	
Tactile Art Access "Action Item" Group TAGS 1	TA Productio n	"If you put a raised line drawing kit in front of somebody and then tell them to draw something on it, a Christmas tree, for example, the will draw a Christmas tree. But when they are done with the drawing, all of the other kids will have already begun adding color to their drawings or doing something else. The blind student will no longer be included...It is important to get children excited about what they are doing and learning at a young age. When they miss out, learning is not as much fun.	inclusive engagement	x	
Inclusive Live Nude Modeling Sculpture	AP	"I have always been and remain somewhat reluctant to put myself in situations where I am gonna be, rather than a participant, an object of view.	unwanted attention due to VI	x	

		And I have gotten better, but I still find yoga classes really stressful.” Another blind artist noted, “we tend to think we [blind people] are the ones who are standing out at some degree...”			
Tactile Graphics Access and Reading Demonstration during TAGS 3	GC	This is something that we encourage children to do but as we get older we start to hear, "Don't touch, and we start to hear that we are not allowed to touch, we are not allowed to touch the grass, we are not allowed to touch all of these things that we want to explore. For instance, we have a tactile gallery in just outside of our offices to display all of the tactile art that we do and we have to tell people, "Yes please touch," because they'll come up and they'll put their hands behind their back and they'll lean over and put their nose almost onto the page because they want to see it and we're like, "No, it's tactile art, it's tactile maps, it's tactile graphics. You're supposed to touch it." We're all here because we want people to touch things and we think that everyone should be touching things, not just blind people, not just sighted people but everyone needs to get lines under their hands.	"We start to hear, Don't touch..need to get lines under hands	x	

Participant discussing a symbol representing wifi	GC	Speaker 1: This symbol is most commonly associated with that for sighted people. That's what we're trying to convey in tactile form, this is what it would look like. Speaker 2: Well mission accomplished because I've never experienced this symbol before. Speaker 3: It looks totally different, there are a million different options that are all the same arched with three or four or five sequential lines and maybe there's a circle at the bottom or maybe it's empty or maybe it's full or maybe it's a little triangle. As you were saying, it's all stylistic. Speaker 1: It is stylistic but this is a pretty common one that a lot of sighted people will know. Yes. Speaker 2: Thank you.	"I've never experienced symbol before"	x	x
Tactile Literacy "Action Items" Breakout Group share out	GC	Speaker 1: Okay, so I guess that the action items we came up with were, need a matrix of tactile book vendors. So note to, we talked about the boards of having tactile books that have tactile content available all across the grades levels, because right now they're kind of focused in an early grade, early elementary is where you have a lot of tactile books. So looking at what is available and trying to make a matrix and trying to fill in the gap	finding tactile reading materials	x	x

		through K through 12.			
Participants introduction during the second TAGS	GC	Seeker 1: I'm really hoping, from this group, to get some ideas because in our time with kids in March and April, we saw 19 children. Six of them were Braille readers and 13 of them were print readers. We found the kids were all over the place and we also found, which I already knew but this really confirms it. We don't have a really clear way to teach kids to approach information and graphics. Not that we want little VI robots out there but we need to give the teachers, the visually impaired students some tools and techniques that they can use so they're more systematic in their approach to the kids ultimately are more successful.	"clear way to teach kids to approach information and graphics"	x	
Participants introduction during the second TAGS	GC	I always felt like the conversation about tactile models, tactile graphics was always sort of an accessibility issue. It's always like, "Okay, you have this visual thing so let's make a tactile so now blind people can feel it." I'm kind of, at this point, interested in, how can we go beyond that [accessibility] and make touch feel normal. It's	"go beyond accessibility and make touch normal"	x	

		not something just specific to blind people but how can we make tactile on graphics so that it's appreciated by anybody. I guess I feel like a blind person, part of my role in all this is to use my own experience to sort of maybe challenge people to explore things in a different way.			
Debrief of tactile graphics production breakout activity during TAGS 2	GP	Speaker 1: I mean, if you're going to make it thermaform, then it's really expensive to add those things on, but it might have been an interesting set out if the furry dog, the one who's supposed to be very furry, if that one was actual texture from cloth. Speaker 2: And also, dogs have a lot of different smells.	"really expensive"	x	
Debrief of tactile graphics production breakout activity during TAGS 3	GP	I found myself having this inner dialogue where I just sat there, because I was under sleep shades, and I was just sitting there, and in my head, I was like, you're sitting there like one of your students! Where you have to tell to reach out and explore and be active, so then I kind of forced myself to reach out and touch what was around me, but I tended to just ... my initial reaction was just to sit very passively, and even when I reached out to explore, I was only exploring what I could feel. So yeah, it would have	Material orientation	x	x

		been nice to have that orientation of just to know it's available. I'm sure I'm only used like one out of the available 10 tools because I didn't know it was there.			

TAGS 3

I performed the same consent protocol as the first two TAGS. All participants consented to the research. I also performed the same data collection protocol as TAGS 1 and 2, but the structure of the event differed slightly. TAGS 3 took place over the course of three days, to allow for travel times to the remote Enchanted Hills Camp. The event began in the mid afternoon on a Friday and ended on Sunday mid morning. After introductions, the first segment of the event focused on tactile graphics consumption. The second day began at 9:00 am with a debrief from the night before and tactile graphics design and production activities. The afternoon sessions focused on tactile art production. After a short break, the participants attended the tactile art gallery opening late into the evening. At 9:00 am the following morning, the group engaged in discussions about the state of art accessibility. The third TAGS wrapped up with small group "Action Item" discussions and a large group conversation to identify strategies for the TAGS community to develop. We ended at 12:00 pm. We performed the same data analysis procedure as reported for TAGS 1 above. I sent approximately 6 hours of audio data to a professional, confidential transcription service.

Retrospective Grounded Theory Analysis

To analyze the data, I performed a retrospective, grounded theory analysis to identify recurring issues and strategies related to consumption, design, and production of tactile media.

Grounded theory methods (Strauss & Corbin, 1994) emphasize data analysis that requires constant comparison of data segments, which leads to the gradual identification of themes in the data and the development and refinement of findings, in the form of a theory grounded in the data.

With all three TAGS data sets in hand, I performed a multi step coding process using Dedoose software (Dedoose ("Dedoose," n.d.). The first round of coding involved identifying segments of dialogue within the transcripts where participants directly addressed the four general topics guiding the design of the TAGS. I refer to these topic areas with Structural Codes, which include: issues related to art consumption, art production, graphics production, and graphics production. I subsequently assigned a word or short phrase from the data as a further label taken from that section of the data (See **Table 4.4** for examples). This method is called invivo coding, a strategy used to ensure that concepts stay as close as possible to research participants' own words or use their own terms because they capture a key element of what is being described (Given, 2008). I then identified recurring topics from among the invivo codes.

I subsequently identified whether the text excerpts associated with the clusters of invivo codes could be considered as somebody sharing their personal experience (of a material, experience, etc.), a direct statement of an area of concern, or a strategy to overcome that area of concern. We used the data coded using this method to write analytical memos to identify and name the recurrence of issues the participants face regarding consumption, production, and instruction of tactile art and tactile graphics.

TAGS Event Design Overview

We designed the TAGS as social learning experiences based on our objective to create a forum where practitioners and scholars who consume, produce, and instruct with tactile media can come together and discuss the issues that impact their practices, compare experiences, and envision solutions. Social learning is "a process of social change through which people learn from each other in ways that can benefit wider social-ecological systems" (Reed et al., 2010, p. 2). Social learning theorists define learning as active social participation in the practices of a community (Lave, Wenger, & Wenger, 1991; Wenger, 1998), and emphasize the dynamic interaction between people and the environment in the construction of meaning and identity (Muro & Jeffrey, 2008). In addition, based on our understanding that talking about tactile media practices are best facilitated through direct experiences, and considering that our participants came to the TAGS with varying degrees of experience consuming, creating, and instructing with tactile media, we planned an event with many hands-on activities. In the design and implementation of hands-on activities and discussions based on these experiences, we also drew on theories of constructionism (Papert, 1986). The theory of constructionism describes human-centered, discovery learning where people use the knowledge and experience they already, and through the process of engaging with materials to build something, construct mental models to understand the world around them.

Activity Descriptions

In the text below, we describe our aim for each of the activities implemented during the TAGS and the basic structure of each activity. The activities we designed focused on building community and directly engaging participants with materials and discussion about art consumption, tactile art production, tactile graphics consumption, and tactile graphics

production. While we did not provide specific definitions of each of these terms to the participants, intending that shared understandings of these terms emerge from the group, we designed the activities based on the following definitions:

- **Tactile Graphics:** Representations of data and information made up of raised lines, areas, textures and symbols, and are intended to be felt rather than seen that are a means by which blind people access maps, graphs, diagrams and other graphical representations (Aldrich, 2008);
- **Accessible Art:** Art created to be accessible through non-visual means or artistic content that is made accessible through sound and labels. One primary type of accessible art is Tactile Art.
- **Tactile Art:** Pictures, illustrations, sculptures, and multimodal compositions that are accessible through the sense of touch. In some cases tactile art is crafted intentionally for touch-focused experiences, in other cases, the label tactile can be applied to art that produces a tactile or haptic response when touched. Tactile art is differentiated from tactile graphics in that it not created with the intent of representing information.
- **Consumption:** The process by which goods [art] and services are put to final use by people; Consumption is at the end of the line of economic activities that starts with an evaluation of is available resources and proceeds through production and distribution of goods and services (or the means to acquire them) among people and groups (Goodwin, Nelson, Ackerman, & Weisskopf, 2008).
- **Production:** Any creative activity involved in the manipulation of materials into a consumable good or service. Production may be referred to as creation, craft, design, and manufacturing. Production practices are agentive in nature, support self-determination

(Sheldon, 1995), and require critical reflection about one's own and other people's agency within social, technical, and environmental systems (Drucker, 2017).

Community Building Focused Activities

TAGS Introductions:

Aim: Welcome participants to the TAGS and provide the overarching vision for the TAGS event and the schedule of events.

Structure: The TAGS commenced with a welcome by the RPP and an overview of the event, guided by the following text:

> "Throughout the years we have made huge inroads into understanding what kinds of art and images can be made accessible to touch. This is a critically important issue. Technological advances have reformed the way we communicate and how many ideas are being conveyed through visual images. Braille bridges the gap to print information. We need to discover ways to span this gap to visual information. The goals of this symposium will be to create a community of educated supporters who will share knowledge and resources while promoting this new experience of art and access to information. The most important reasons to have this gathering are to 1) Touch good examples of tactile art and tactile graphics. Tactile art must be felt to be known. 2) Meet with leaders in the field to gain a deeper understanding of the different forces that shape the field of tactile art and graphics; 3) Learn about new ideas, technologies, materials and techniques making advances in the field of tactile art possible; 3) Gain a broad knowledge of the state of tactile art so that all participants are aware of tools that have been successfully applied to tactile art; and 4) Expand our impact by publishing findings,

insights and plans to reach as broad an audience as possible and invite more people to contribute."

In addition, NFB President Riccobono provided a formal welcome from the NFB, which can be seen in **Appendix.**

Participant Introductions:

Aim: Introduce participants to one another and determine their goals for attendance.

Structure: Participants spent up to 5 minutes introducing themselves, typically describing their name, professional affiliation and role, and/or their interest in tactile media and goal for the TAGS.

TAGS Community Action Item Group and Debrief:

Aim: Create a forum for participants to further discuss topics of interest and identify resources and strategies for themselves and others.

Structure: Participants gathered in a small groups of three to five people for one hour to discuss strategies to advance the TAGS community. At the end of the hour, they shared their ideas out to the whole group.

Communication Action Item Group and Debrief:

Aim: Create a forum for participants to further discuss topics of interest and identify resources and strategies for themselves and others, specifically relating to communication with outside groups.

Structure: Participants gathered in a small groups of three to five people for one hour to discuss strategies to communicate about the importance of tactile media with outside parties. Subsequently, they shared ideas with the large group.

Tactile Art Consumption Focused Activities

Tactile Art Exhibit Creation and Opening:

Aim: Provide participants with an in situ tactile art consuming experience through which together they would identify "touch points" or common reference points from which discussion could emerge. In addition, we aimed to demonstrate for the participants and the host sites (the NFB, UCAR, and the Lighthouse for the Blind, Enchanted Hills Camp) how to create art access through pop-up exhibits **(Figure 4.1).**

Structure: We contacted 20+ tactile artists to ask for art contributions to the exhibit, arranged shipment and installation of each piece, and developed accessible printed text, Braille, and audio descriptions. We selected work created by blind and sighted artists, using a broad array of materials and different styles of art. The art pieces were available to participants throughout the TAGS and were drawn upon during the following Art Fitness 101 activity[23]. During each of the TAGS, we hosted a Tactile Art Exhibit reception for the participants and other art patrons in the community.

Figure 4.1. Tactile Art Exhibits. (Left) TAGS 1; (Middle) TAGS 2; (Right) TAGS 3.

[23] Art Fitness 101 a trademarked activity used with permission from the developers at the Museum of Contemporary Art, Denver.

Art Fitness 101 Activity:

Aim: Provide participants with a technique to focus their attention on the nuance of interpreting the art showcased in the art exhibits.

Structure: We asked participants to explore each piece of art under sleep shades and to reflect on a series of questions: 1) What can you feel (through the sense of touch)? 2) What would it mean if something was different? 3) What was the artist's intent? To support participants in answering these questions, the RPP encouraged the participants to explore the artworks under sleep shades to hone their sense of touch and engage in Structured Discovery—a training method used at the NFB Independence Training Centers to help students under sleep shades identify what mobility and orientation and exploratory procedures work for them. Instructors using structured discovery intentionally guide their students in the construction of their own knowledge and skill with respect to independent travel through asking questions about the environment; the instructor reinforced the student's answers when they lead in a positive direction, and redirects the student's thinking only when they give up or get off track. (Maurer, Bell, Woods, & Allen, 2006).

"Insects Playground" Interpretation Activity:

Aim: Engage participants in exploration and critique of specific design conventions used in the design of bas-relief sculpture—reproduced in thermoform—titled "Insects Playground" that represent plants and insects, situated in a landscape with different levels of plant growth **(Figure 4.2).**

Structure: Before asking participants to explore the representation, we described the sculptures and elements in relation to each other so that participants had a mental map of the space. We

asked participants to take note of their experience with the materials and then share their experience with others.

Figure 4.2. Plants and Insects Playground Sculpture. (Left Image) Thermoform bas-relief replica; (Center) TAGS 1 Participants feeling and critiquing the thermoform replica; (Right) Reproductions of the sculpture using different production materials and technologies.

Defining Tactile Art:

Aim: Support the participants in developing a shared definition of tactile art

Structure: Participants broke into small groups to discuss three questions, and then report their answers back to the large group: 1) What design elements are essential in tactile art for the viewers to understand the meaning and intent of the artist?; 2) What aspects of the art pulled you into the experience?; 3) What aspects of the art presented barriers to your experiences?

Accessible Art Museum Discussion:

Aim: Engage participants in a discussion about the state of accessible art exhibit curation.

Structure: In a large group setting we led a discussion, guided by three questions: 1) How do we curate tactile art exhibits that entice people to approach the work from their sense of touch first?; 2) How do we curate inclusive museum experiences for blind patrons?; 3) How do we make tactile art more mainstream so that the general public experiences this form of art, and so that the general public is exposed to accessible art experiences and patrons?

Accessible Art Museum Collections Demonstration:

Aim: Engage participants in a discussion about the state of accessible art exhibit curation.

Structure: A curator at a California-based Jewish art museum and a professor of disability studies led a large group to discuss their experience developing an accessible art exhibit at a California-based Jewish art museum. The curator and professor described their experience and answered questions and comments as they arose.

Tactile Art Access "Action Item" Group and Debrief:

Aim: Create a forum for participants to further discuss topics of interest and identify resources and strategies for themselves and others.

Structure: Participants gathered in a small groups of three to five people for one hour to discuss the characteristics of tactile art, creating a viable market for tactile artists, and accessible museum exhibit design. At the end of the hour, they shared their ideas out to the large group.

Tactile Art Creation and Production Focused Activities

Tactile Art Production Method Comparison Activity:

Aim: Engage participants in the critique of production methods used to create tactile bas-reliefs.

Structure: We presented participants with replicas of "Insects' Playground" bas-reliefs, reproduced using different materials, such as foam, plastic, thermography, swell paper **(Figure 4.2).**

Tactile Art Creation Breakout Groups and Debrief:

Aim: Engage participants in creating tactile art and reflecting on their practice.

Structure: Participants visited three tables set up with activities. Depending on the event, the tables focused on: clay sculpting, collage, wire sculpting, creating dynamic spinning sculptures,

lapidary arts, and/or stone carving. In small groups, participants spent 20 minutes at each table, creating their own pieces. Afterwards we led a large group discussion focused on three questions: 1) What did you feel most comfortable doing?; 2) What surprised you about your ability to do these activities?; 3) What would you need to successfully use the techniques?

Inclusive Live Nude Modeling Sculpture Class Demonstration:

Aim: Share successful strategies for developing inclusive art creation experiences.

Structure: An artist, writer, and educator who is BVI and an instructor from the Palette & Chisel Academy of Fine Arts to led a large group demonstration about an inclusive live nude figure modeling class, and answered participants' questions about how the BVI artist was positioned to observe the nude model and navigate using touch to guide her creation process.

Tactile Art "Action Items" Break-Out Group and Debrief:

Aim: Create a forum for participants to further discuss topics of interest and identify resources and strategies for the TAGS participants and others.

Structure: Participants gathered in a small groups of three to five people for one hour to discuss strategies to empower BVI people to become artists, and to empower other artists to create tactile and accessible art. At the end of the hour, they shared their ideas out to the large group.

Tactile Graphics Consumption Focused Activities

Tactile Graphics Demonstration:

Aim: Introduce all TAGS participants to the methods and technologies and materials that are available for consumption.

Structure: We passed around objects created by a variety of technologies and discussed the advantages and disadvantages involved in producing tactile graphics (e.g.,., cost, feeling,

robustness, etc). The technologies covered in the presentation included specific products, such as: Sensational BlackBoard and Sensational Drafting Board, inTACT Activity Sets, TactiPad, STEM Binder, Swell paper and Machines, Thermaform, Embossers, and 3D Printers, and audio labeler pens.

Tactile Graphics Access and Reading Demonstration:

Aim: Share successful strategies for consuming and interpreting tactile graphics.

Structure: For TAGS 3, we invited two sighted tactile graphics designers from a San Francisco-based tactile media design lab to lead a large group discussion and demonstration about the design of tactile graphics. The activity leaders distributed a booklet of tactile maps and symbols to each participant, which they subsequently used to demonstrate a series of teaching and learning strategies used to engage people in reading tactile graphics.

Tactile Graphics Consumption Breakout Groups and Debrief:

Aim: Engage participants in reading/consuming and reflecting on the design of tactile graphics.

Structure: Participants worked in small groups to examine and critique a two-foot tall human skeleton, a bas-relief children's picture book, and raised line tactile maps. Participants spent 20 minutes at each table, after which we led a large group discussion.

Tactile Literacy "Action Items" Breakout Group and Debrief:

Aim: Create a forum for participants to further discuss topics of interest and identify resources and strategies for the TAGS participants and others.

Structure: Participants gathered in a small groups of three to five people for one hour to discuss how to get graphics in the hands of students, support families acquire and use tactile graphics, develop multimodal activities, and/or teacher training opportunities.

Tactile Graphics Production Focused Activities

Tactile Map Design and Production Demonstration:

Aim: Share successful strategies for producing tactile graphics.

Structure: For TAGS 1, we invited a blind artist, engineer, and researcher who discussed and demonstrated his experiences producing tactile maps. He primarily focused on strategies to design successful graphics for consumption and answered participants' questions.

Inclusive Tactile Graphic Design Activity:

Aim: Engage the group in a hands-on activity focused on inclusive tactile graphics design.

Structure: A BVI artist guided the other participants, in a large group setting, to create a line graph using tactile materials. Each participant received a set of materials to create tactile line graphs. After everybody completed their graph, the group discussed what strategies were helpful during his or her design process.

Tactile Graphic Design Breakout Group and Debrief:

Aim: Engage participants in designing tactile graphics.

Structure: Participants broke into small groups to engage in creating tactile graphics. The participants in each group spent 20 minutes at three different tables, with materials to create graphics, including Braillers to create embossed graphics, foam and other paper and wiki sticks to collage graphics, a Sensational Blackboard to create raised line drawings, a computer to attribute metadata to graphics, and motors to add dynamic movement to graphics. Afterward, we led a large group discussion.

Tactile Production Considerations "Action Items" Break-Out Group and Debrief:

Aim: Create a forum for participants to further discuss topics of interest and identify resources and strategies for the TAGS participants and others.

Structure: Participants gathered in a small groups of three to five people for one hour to discuss strategies to support tactile graphics designers. At the end of the hour, they shared their ideas out to the large group.

Iteration and Variation

It is important to note that we did not implement all of these activities at each TAGS; differences in time logistics, host site requirements and accommodations led to some variation. In addition, our experience of implementing the early TAGS provided us with insight into how to improve the flow of the events and led to slight changes in the design of the later events. For example, many of the activities we implemented as large group activities during the first TAGS shifted to become small group activities so the participants could have more first-hand contact with materials and engage in more focused conversations. **Table 4.5** represents the activities we implemented across the three TAGS and the variation in the programs.

Table 4.5. Implemented TAGS Activities and Variation in the Programs.

	TAGS 1	TAGS 2	TAGS 3
Community Building Focused Activities			
TAGS Introductions	x	x	x
Participant Introductions	x	x	x
TAGS Community "Action Item" Group	x	x	x
Communication "Action Item" Group			x
TAGS Future Actions			
Tactile Art Consumption Focused Activities			
Tactile Art Exhibit Creation and Opening	x	x	x

Art Fitness 101 Activity and Discussion	x	x	x
Insects Playground Activity and Discussion	x	x	x
Defining Tactile Art Discussion	x		
Accessible Art Museum Discussion	x		x
Accessible Art Museum Collections Demonstration			x
Tactile Art Access "Action Item" Group	x	x	x
Tactile Art Creation and Production Focused Activities			
Tactile Art Production Method Comparison Activity and Discussion	x	x	x
Tactile Art Creation Breakout Groups and Debrief		x	x
Inclusive Live Nude Modeling Sculpture Class Demonstration			x
Tactile Art Creation "Action Items" Break-Out Group		x	
Tactile Graphics Consumption Focused Activities			
Tactile Map Demonstration	x		
Tactile Graphics Access and Reading Demonstration			x
Tactile Graphic Reading Breakout Groups and Debrief			
Tactile Literacy "Action Items" Breakout Group	x	x	x
Tactile Graphics Production Focused Activities			
Tactile Map Design and Production Demonstration	x		
Inclusive Tactile Graphic Design Activity and Discussion	x		
Tactile Graphic Design Breakout Groups and Debrief		x	x
Tactile Production Considerations "Action Items" Break-Out Group			x

Findings

In this section we present an analysis of the data that emerged during the TAGS that answer our first two research questions:

1. What are the factors/issues that impact the art and graphics consumption, production, and instruction, practices of participants who attended the Tactile Arts and Graphics Symposia (TAGS)?
2. What strategies do the TAGS participants identify as contributing to or inhibiting access and participation?

We draw on this organization in the presentation of the findings. In Findings A, we first present the issues that emerged pertaining to each of the four tactile media practices (Structural Codes). Subsequently, in Findings B: Strategies, we present the specific strategies that participants identified to address these issues. In the Discussion section we address Research Question 3: What do the factors/issues and strategies reveal about the problems of practice related to tactile media that the TAGS participants, and in turn similar stakeholders, encounter?

Findings A: Issues

I. Issues Related to Art Consumption

BVI Desire the Opportunity to be Consumers of Art (AC1).

Participants in each of the TAGS universally agreed that there is an extreme dearth of opportunities for people who are BVI to access art. Throughout the TAGS the participants explained that by not having access to artistic content they are not able to gain access to important cultural information or participate in viewing art or activies that develop their artistic preferences. The lack of access to artistic materials is a barrier that people who are blind face regularly. A TAGS participant, who is blind from birth and participates in the design of STEM graphics, reflected,

> "When going to art museums I feel like I am held behind the glass." She continued, "But that is not what art is! As blind people, we have a lot to contribute to this conversation!"

Another TAGS participant who identified as an artist and who is progressively losing sight shared,

> "To be able to experience what a Van Gogh or a Matisse or a Picasso feels like would be a very important thing for anyone's development, and it's been a long time since I've had the opportunity to experience that for myself, so I would like that chance again."

A TVI and researcher shared that she is interested in finding a way to replicate tactile art consumption experiences in her home state, where

> "Art education funding for all students has been dramatically cut—not just affecting blind students."

A third participant who is a museum curator reflected,

> "I just think for children who grow up blind and aren't exposed to what art in the world means or has taught us, it would be great if there was a way to bring that knowledge to them, to help them find that knowledge."

A Lack of Consistency and Diversity of Accessible Art Affects BVI Consumption Experiences (AC2).

The TAGS participants identified that the lack of opportunities to access art is compounded by the fact that museums and other cultural institutions do not provide consistent experiences (at the institution or between institutions) nor a diversity of artworks, e.g. art created in different medium or art created in different styles. For example, during the third TAGS a BVI artist and educator noted,

> "I am somebody who any opportunity I have to get my hands on art I leap at the chance. And so I have taken advantage of all sorts of official museum touch tours at museums

around the world. And for anybody who's ever done that, you will know that the quality of these opportunities varies wildly. Sometimes it is really rewarding. Sometimes it is essentially a waste of time, but I will leap at the chance."

Regarding diversity, a BVI assistive technology specialist noted,

"I am used to going to a gallery that might have two or three tactile objects."

Another participant noted,

"It is very common to only be able to see sculptures when visiting art museums."

BVI Receive Unsolicited Attention when Being a Patron of the Arts (AC3).

The TAGS revealed that people who are BVI receive unsolicited and in some cases unwanted attention from other patrons or museum professionals when they visit museums. An access media specialist who is blind shared,

"When I go to art exhibitions and want to touch the art, one thing that stands as a barrier for me is when I feel like I am part of the exhibit; when my experience as a blind patron becomes the focus of the other people's attention. It really distracts me from what I am there to experience."

Describing her experience, an accessibility advocate who is low vision noted,

"My husband and I had an experience at the Louvre three years ago. I had purchased the tickets ahead of time online. When we get to the Louvre and get to the person collecting the tickets, and she is like, 'Well you can get in for free, you do not have to pay [because you are blind]. I am like, 'But we have already paid.' And she started arguing with us. 'No, no. You can get in for free.' I am like, ' We have already paid! We want to support the museum. We are happy to do that."

In reflection of her art viewing experience during the third TAGS, an artist reflected,

> "There wasn't anybody watching me over my shoulder...I wasn't worried about how long I stay there in the room...It was really just a glorious experience to be able to look at something, and then can move on, and decide that you want to go back and look without fear of being judged."

Many Museums and Cultural Institutions Do Not view Tactile Art As an Asset for All. Rather, it is Seen as a Mandate or Something 'Special' for BVI (AC4).

The TAGS participants noted that many museums and other cultural institutions approach accessibility as a mandate, (e.g. American Disabilities Act), as opposed to seeing access design as an avenue to create exhibits that are more enjoyable for all. In addition to viewing access to art as transactional or as a mandate, the TAGS participants noted that tactile art is often only viewed as a resource for people who are BVI, which perpetuates a "ghettoization of different populations of patrons". During an introduction at the third TAGS, a museum curator shared her professional goal to explore new approaches to the development of inclusive museum programming.

> "How do we move the idea of access out of just sort of the transactional, service model, and really think about it creatively so museums and arts and cultural organizations don't just think of it as the law, but as a strategy to support all patrons."

At the onset of the first TAGS, a BVI advocate and policy maker declared,

> "Until the idea of tactile art is embraced as a mainstream item, there will continue to be a separation between our appreciation of art and the general public's appreciation of art. We [the blind community] have created some industries—we have created the access technology industry...The companies that make assistive technology have come to recognize that [their product development] benefits all of their customers—not just blind

> customers….Similarly, we have to help the industry come to know that multisensory art is part of what is needed for all populations."

During a later symposium, a BVI artist and write noted,

> "I think the only way that, as blind people, we are really going to get access to art and all sorts of other things by starting to break down some of that prohibition for sighted people, trying to let sighted people recognize how valuable touch is."

BVI Experience A Stigma When Touching Art (AC5).

Many of the TAGS participants' indicate that when using touch as a vehicle for consuming art they experience a sense of stigma; the stigma imposes a limitation on when and how they engage in tactile exploration in fine art and other cultural environments. As one TAGS participant noted during the first event,

> "I feel strongly that touch is a very maligned sense. It is the only sense that we have that people constantly tell people not to use it. No one ever says, 'Don't look. Don't listen. My god, don't taste that.' But we commonly, commonly, excessively hear, "Don't touch."

Others provided descriptions of their experiences; a blind artist and craftsman recalled,

> "They [an art museum] had this cool kinetic sculpture just outside of the door. I walk out there, and I stick my hand in it and this really sweet docent, who comes up to me and says, 'You cannot touch that. You know, you get sand on your face, and it gets on the floor, and people got to clean that up."

The impact of such experiences is that many people are hesitant to use their sense of touch as a means to explore their environments. During the second TAGS, a director of an independence training center said,

> "Most people are taught not to touch and not to be aware of their full environment. I think it is critical that that changes."

Inaccessible Exhibit Configuration and Layout Inhibit BVI People from Accessing Art (AC6).

Throughout the TAGS, participants noted that access to tactile art requires intentionally designed displays. This issue emerged after participants had an opportunity to access art in the TAGS art exhibits. During the third TAGS, one participant noted,

> "I almost hit my head on the shelf because I didn't realize that was there. So maybe if the shelves weren't there if they don't need to be that would be very helpful."

The TAGS participants also remarked on how the positioning of labeling in relation to the art piece can be very important. In one case there were audio labels positioned on a piece of art. One participant noted that the audio labels got in the way of her tactile viewing.

The Prevalence of Ineffective Labeling (on visual and tactile art) Affects the Accessibility of Art for People who are BVI (AC7).

The TAGS participants repeatedly shared that art pieces—tactile or not—that do not have Braille or audio labeling and ergonomically placed labeling, greatly limits their interest and ability to understand the content within a piece of art. For example, a person who is blind noted, "It is difficult to understand the artist's intent when there is no additional—textual or auditory information." Another participant noted that when labels are not placed effectively, the can "confuse one's ability to tactilely interpret the art pieces." During the third TAGS art exhibit, several participants noted most of the time Braille is stuck to the wall, despite the fact that"reading Braille vertically against the wall it is really hard and tiring."

Touch Affects Artistic Materials (AC8).

While discussing the experience of touching art, many of the TAGS participants raised the concern that touching art will have a lasting impact on the media. A cultural and visual anthropologist who is sighted noted,

> "People talk about the fragility and the notion of degradation...Some of the pieces like the stone or the wood become activated by touch….As people know to touch them those impressions start to wear, and you will be able to see that sort of generation of people who have touched them, felt, and they will become smoother in some places....the oils will accumulate. The oils will start to accumulate, and we tend to view that all as degradation. ; in some worlds, that is a bad thing, but in other words, it is good...I would want to encourage this sensation of connectivity to the past, to previous generations."

Another researcher commented on the value touch adds to different materials,

> "There is beautiful ephemerality to touch. It can have both lasting impacts—for example when the oil from one's hands transfer to a stone or no impact at all."

During the second TAGS, a tactile graphics producer was a bit more cautionary and said,

> "If the artist knows the piece is going to be touched, they will know that the piece will be short-lived."

BVI are not Exposed to Education focused on Touch-Based Art Interpretation (AC9).

The TAGS Participants shared that many people who are blind are not exposed to educational experiences that prepare them with knowledge about how to find and access art and how to approach a piece of art once they have gained access. For example, during her introduction at the second TAGS, a participant who is blind and an artist said,

> "As a blind person, art is still really important to me and it is important to both people to have access to descriptions...I could go to Google, where I would find out how limited the audio descriptions of images of certain works of art. My passion, I guess, is in be able to get other people to know those things because if you have never experienced it, how do you even know it is out there?"

In reflecting about the third TAGS art gallery, a TAGS blind artist noted,

> "It was interesting to see that I was having problems with myself and then even when I did touch the art…we might need to work on is teaching people how to touch the art."

To the same point another participant who is an artist and is BVI noted,

> "I had to find out on my own that there are a lot of different ways to touch art... So there's a very delicate touching with the fingertips. There's touching that happens with the whole hands, the whole fingers. There's touching that evolves enveloping the object, a 3D object with the whole hand. Grasping, pinching, tapping, lifting, circulating, manipulating, grasping with the hands and the upper arms, and so on."

Another BVI participant noted,

> "One needs enough knowledge of the piece before they start to look at it so that they can enjoy that aspect of it...I tend to have incredibly super, super light touch so I would have never pushed it."

An art educator provided an example of her experience working with children who are blind; she exclaimed,

> "Last night I think all of you, as adults, were very gentle with your touch. You were taking your time. However, I also work with children and if I told my kiddos, 'We are

> going to a tactile art gallery,' they would have wrecked everything...they are just the most curious, engaged, kids ever."

A blind artist, designer, and researcher noted,

> "When we talk about art and access…I always react...I always feel like Art with a capital A is a privilege. I want to reject that- Art is an expression of a combination of elements— it surely isn't just visual...We have a long history of blind artists that have been working in blind media forever, we are not innovators. We rediscover stuff; we are rediscovering a long history of experience and achievement. I am really interested in how we develop the skills in kids— spatial skills and a deep relationship of how they work."

The need for more opportunities to learn how to interpret art became apparent during a conversation about abstract and representational art. A TAGS participant who is BVI noted,

> "We talked about whether the meaning of abstract art could be conveyed non-visually and whether abstract art can be meaningful to blind people...Tactile forms may be pleasurable to touch, but not inherently help convey the intention of the artist or the meaning of the artwork."

During the second TAGS, a museum curator said,

> "Some things are not meant to be intelligible, at least in the literal sense. With some [art pieces] the intention is rather to provoke internal questioning, thinking about what the objects are. If it is important for the interpretation of the piece, for something to be understood, then obviously the components have to be intelligible in a tactile way or through labels."

BVI and Others Yearn for Opportunities to Discuss Touch-Based Art Interpretation (AC10).

During the TAGS art exhibit debrief conversations, many of the TAGS participants noted that it is very rare for them to have an opportunity to discuss their experience of touching the art. In reflection on his experiences with different art pieces at the second TAGS, a blind art teacher and craftsman noted,

> "There's such a difference between touching it and exploring with your sense of touch…. I want to reflect on how we touch things, how we take the time to explore it with their fingers and their senses."

Similarly, a sighted person attending the second event focused on the connection between the physical experience of touch and the emotional experience of a piece of art.

> "We tend to think of touch as fingers touching a surface, but we might expand what that means...it means that your whole body is involved that you are moving, it means that you are emotionally engaged. To expand the meaning—beyond fingers touching."

Defining Tactile Art of Accessible and Tactile Art (AC11).

Throughout each of the TAGS, participants debated about what constitutes accessible art and tactile art. Their concerns centered not on identifying a specific definition, but on the impact of identifying art as accessible or tactile art. A tactile graphics producer who is sighted noted,

> "I think that part of the problem is differentiation of whether something is 'tactile' art or not. The reason my art is tactile is not that I set out to create tactile art. It is because, in order for it to be meaningful to me, it has to be tactile. I do not have to actually think about it as tactile art...I just think of it as art, and I think that a lot of the other artists here don't think of it as tactile art...It is just art."

Another artist, engineer, and researcher who is blind asked,

> "Do we actually need to know that it is tactile art? A sighted person can still look at it and if there are tactile and haptic aspects to it that are wonderful."

No Universal Vocabulary to Describe Tactile Art Expression and Experiences (AC12).

While trying to describe different pieces of tactile art and the tactile experiences they evoked to one another, the TAGS participants missed having an agreed upon lexicon or vocabulary to describe the ways specific materials feel, the different approaches to touch, and/or the different effects of touch. During the first TAGS, an artist who progressively lost his sight said,

> "I am really interested in how to create tactile art and haptic art that elicits the same profound or meaningful feelings or thoughts, whether it is emotional or intellectual, in the viewer or participant, whatever you want to call them. How can that language be created? We do not even have one yet, really, where we can uniquely develop it."

To this point, many of the TAGS art exhibit discussions revolved around trying to communicate and define terms that described the tactile experience. For example, a blind artist at the second TAGS explained her experience of viewing experience art through the sense of touch.

> "When you first experience something [through touch] it can be shocking, or when we first experience something it could be soft. But when you experience something in a different sequence or context, your experience changes…Maybe there's a story arc that a lot of these pieces do have, maybe more of a story arc than what just visual, the experience of a visual art piece might have..or a Discovery Arc."

During the second TAGS a participant, who became Blind later in life, focused the group's attention on a "3D bas-relief sculpture" and noted,

> "My first reaction to that before we read the description was that I would call that a 2D sculpture because it's not bas relief because it is more of a sculpture that you can walk around…to me, that is a specific type of structure form, but we really don't have a word for it".

This comment incited a discussion amongst the participants, during which the artist who created the piece described,

> "Well, it might be a two-sided bas-relief, with two different images. Like you know, sometimes they have one picture on one side of a page, and then another picture on the other side that has no relationship to the one. But this [type of bas-relief that you experience through touch] definitely integrates[the images] into one another."
>
> Several suggested words included mirroring and silhouette.

II. Issues Related to Art Creation and Production

Being BVI Impacts One's Opportunity but not Desire/Need to Create (AP1).

Several of the TAGS participants noted that inclusion of BVI people in art production activities is important to their inclusion and sense of agency in learning and throughout life. During the first TAGS an educator who is blind provided an example of a scenario that BVI children often face in mainstream classrooms:

> "If you put a raised line drawing kit in front of somebody and then tell them to draw something on it, a Christmas tree, for example, the will draw a Christmas tree. But when they are done with the drawing, all of the other kids will have already begun adding color to their drawings or doing something else. The blind student will no longer be included...It is important to get children excited about what they are doing and learning at a young age. When they miss out, learning is not as much fun."

During the second TAGS an artist and art educator who experienced sudden onset blindness as an adult emphasized the importance of art practice for her sense of agency and ability to communicate.

> "When I went blind, basically in a day, without notice, being able to write and read what I wrote was impossible. Being able to feel like I was expressing myself and not having it be done through a filter or another person was a real struggle. And so, being able to create tactile art has been a really big method of communication for me."

Prohibition and Stigma of Touch Affects If and When BVI Create (AP2).

Many of the TAGS participant's experiences indicate that exploring and creating through the sense of touch has a social stigma associated with it. A blind artist shared that when engaging in art creation, she has been forced to confront a "culture that prohibits and stigmatizes touch." She explained,

> "I have spent so much of my life fighting to get to do stuff that other people are telling me, no, no, you cannot do it. Here's the situation where somebody is saying to me you can do it [live model sculpting], and I am feeling resistance, it is like okay, let's get over this because this is really an opportunity."

During the third TAGS, an art teacher who teaches sculpting explained that he spent a lot of time fretting about how to tell his school administration that he was working with a live model and a BVI student to create a learning environment where she could touch the live model to gather information. He was afraid of being reprimanded for allowing touch.

BVI Have to Overcome Being a Spectacle or Not Belonging when Publically Making Art (AP3).

Accessing opportunities to engage in art creation presents some people who are BVI with psychosocial barriers, including the fear of not belonging in art studios or classrooms, standing out, or being observed. As one participant attending the third TAGS noted,

> "I've gotten better about it over the years but I've always been and remain somewhat reluctant to put myself in situations where I'm gonna be, rather than a participant, an object of view. As somebody who still has a bunch of sort of baggage around being seen by the rest of the class as being this special person up there, possibly getting in the way, possibly getting special privileges...possibly, possibly."

The artist who led the discussion about joining a studio art class with a Live Model reflected,

> "When I go into certain kinds of situations, I'm just so motivated by wanting to do it, wanting to have the experience that I don't care what other people think. I really don't. You know? I mean if you're gonna stare at me, go ahead, you're gonna stare at me when I walk down the street too, you're gonna stare at me no matter what I do. So go ahead, stare, be happy."

Another blind artist noted,

> "We tend to think we [blind people] are the ones who are standing out at some degree..."

An artist with low vision attending the third TAGS remarked,

> "When you go into an art school as a blind person, visually blind person or disabled person, you have this feeling. like here's the psychological barrier that you feel, like I'm not supposed to be here...because this tradition is so hyper-visual."

To this point, another blind participant shared,

> "A time long ago when I went to my first year of art school, I was not confident with my blindness. In fact, I did not call myself blind even though I was definitely suffering from the effects of RP without the confidence and/or the training. I was [taking]drawing classes just trying to do the best I could under the circumstances, but I didn't feel like I belonged or it was just not enough."

BVI Desire, yet Miss Opportunities to tactilely Observe in Art Studio Contexts (AP4).

Few of the TAGS participants who are BVI had experience taking art classes, let alone art studio art classes where they were allowed to touch the materials beyond those they were provided. A blind artist attending TAGS noted,

> "Any serious artist at some point in their training, they work from live models...At this stage, I had taken a number of sculpture classes over my life. And usually, work from my imagination or work from plastic models...but I was always very aware that I was missing the opportunity to observe. Everybody else in the class would usually be looking at a lot of what was sitting there. I felt like this was a piece of art instruction that I was gonna always be missing and would have to compensate for in other ways."

Lack of Art Training for TVIs and Lack of TVI Training for Art Teachers (AP5).

Throughout the TAGS several TVIs identified that there is a lack of training for TVIs to learn about art instruction for their students, or how to coordinate with art teachers to make art experiences accessible to BVI students (and vice versa). For example, a TVI at the first TAGS noted,

> "Learning and appreciation of art should come through the public schools; however, my experience as a TVI was that I received no training on how to accommodate students.

> When I began my career as a TVI, I asked my mentor about what to do, they did not have any idea. They said, 'It is just art, it does not matter.'...This is a common attitude."

During the first TAGS an educator who is blind provided an example of a scenario that BVI children often face in mainstream classrooms:

> "If you put a raised line drawing kit in front of somebody and then tell them to draw something on it, a Christmas tree, for example, the will draw a Christmas tree. But when they are done with the drawing, all of the other kids will have already begun adding color to their drawings or doing something else. The blind student will no longer be included...It is important to get children excited about what they are doing and learning at a young age. When they miss out, learning is not as much fun."

A TVI and behavioral therapist from an early intervention center noted,

> "I spend a lot of my own time trying to come up with new ways to help kids integrate with their surrounds and experiences that are accessible to other children...but I don't feel prepared to create art experiences."

During TAGS 3, another TVI shared,

> "Teachers of the visually impaired need training in art and art teachers need to learn about the role of a TVI and how to utilize them in the classroom."

This echoes a statement made by a TVI attending the third TAGS, who remarked:

> "Just a couple of weeks ago, I was giving a presentation at an art educators conference, and my topic was 'Visual Art for the Visually Impaired.' I asked the teachers attending if they had blind students in their classrooms. Many of them do. I then asked how many of them are working with their TVIs to develop strategies to include the blind students in

> their lessons. The typical responses I got were, ‘what?' ‘who?' They did not know that TVIs exist.”

BVI Need Opportunities to Be Teaching other BVI People (AP6).

The hands-on creation activities as well as the demonstration of how to make studio art classes accessible provided the TAGS participants with a unique opportunity to learn artistic strategies from other people who are BVI. During these experiences, the TAGS participants reflected that it is important for people who are blind to have role models. During the Inclusive Live Nude Modeling Sculpture Class Demonstration, participants asked many questions that could only be answered by another BVI person. For example, one participant asked,

> “So, would you like, plan to do that in the beginning so that you were not blocking people's points of view that was trying to draw some things so that you were not disrupting like their process? Or would you kind of wait until a break or would it be just completely random when you needed the information you went and got it?”

Another participant noted,

> “One of the key things in doing a sculpture of a drawing of anything is measuring proportions, the proportion of this part to that part. So I am assuming you do not just touch a knee or shoulder...you must need to touch more than one place at the same time.”

In a follow-up, several participants inquired as to whether the sense of proportion might be better perceived through touch; if touching the model results in more proportional or muscular detail, and if a blind person is at an advantage by not being able to focus on a “blemish or misconstrued element of the sculpture?” Another participant asked,

> “How close of representation do you end up with to who the model is? Because blindness is a different perspective. When you associate what you are doing through touch

compared to associate what you are doing through your visual, how close do you get to what the other people in the class are getting as far as the representation?"

Lack of Access to Accessible Tools and Materials Inhibits BVI's Art Creation (AP7).

During the TAGS several BVI participants noted that during their childhood they were not exposed to or supported to use the same art materials as their peers. One participant reflected about this experience in art class at school,

"I was only allowed to use clay. I was never allowed to draw. I always felt left out."

During the second TAGS, a sighted computer science researcher reflected that people who are BVI do not have access to many digital design tools. He noted,

"There is a great need to provide better access both to creative tools but also to creative works."

An art educator who is BVI reflected,

"Probably 60% of the kids [who are blind] come to this camp over the summer course of the summer wouldn't have known what the tools on the table were. There has to be an orientation to what a tool does to proceed and get people then to move on to do the creative part. I know that lots of times, we jump into processes without properly teaching people how to use the tool to get to the process."

An art teacher noted,

"I think it's just really important to remember with this that it is about the exploration and not necessarily the end result. It is important for the kids to learn how to use space and materials and how important they are.

Many Tools and Materials Are Not Accessible To BVI (AP8).

While engaging in the activities focused on art creation, the TAGS participants noted that tools used to create art are not accessible. For example, an access technology specialist noted that

> "a lot of creation technologies are so new, we really need to build maybe a collaborative forum to get user feedback about the inaccessibility of these tools."

During TAGS 1 a participant with acquired blindness shared,

> "I used to love graphic design. Now, I don't even know where to begin. All of the design programs I used are no longer accessible to me."

III. Issues Related to Tactile Graphics Consumption

Many BVI are Not Exposed to Tactile Graphics (GC1).

Many of the BVI TAGS participants shared that they have not had access to tactile graphics—both as young learners and adult learners. For example, during the first TAGS a participant who recently acquired blindness reflected,

> "I have seen a lot of art and graphics as a sighted person, but my experience as a blind person has been surprising- there has been a huge absence of accessible art and a huge lack of information."

During the same event an advocate who is BVI shared,

> "I never learned about graphics or maps as a child."

Several of the TAGS participants who produce tactile graphics also shared their encounters with other people who had never accessed tactile maps before. One producer noted,

> "We spend a lot of time getting feedback on the maps that we make. People often say they are great, that they love them, they say 'they are gorgeous,' but then they ask, 'but

> then what do we do with them?' These people who are looking at these maps had never been exposed to tactile graphics before."

Similarly, when describing a project that provided people with tactile maps of their neighborhood, a blind researcher, artist, and engineer recalled,

> "Many people would be crying...it was surprising to me how many people got emotional when they saw these maps...They would recognize the streets that they knew...I came to realize that people were emotional about getting access to this kind of information—that had never been available before. It is something that so many of us have always wanted and needed. Many of us stopped thinking that it was something we could have."

An astrophysicist who recently became aware of the dearth of accessible STEM exhibits noted that many exhibits that are labeled as accessible are "insignificantly available."

Tactile Graphics to Teach Math and Spatial Literacy are Very Limited (GC2).

TAGS Participants noted that tactile graphics are important resources for teaching and learning math and spatial literacy skills; a lack of tactile graphics and aligned curriculum to support learning affects a BVI person's career prospects. A blind researcher in the field of haptic perception and haptic displays squarely identified that:

> "Spatial literacy for blind people is becoming really important for the workplace and I think it's something that we have to send people out into the world with skills that they can bring with them to accomplish the jobs they need to."

A TVI who is visually impaired and works with middle school students and is a professor of practice in a department of disability and psychoeducational studies noted that there is much need to teach BVI students

> "skills around solving math word problems so they'd be more successful when they get to algebra... If you are not successful in algebra, you are going to be much less likely to go into the STEM field."

She later elaborated that there is a need for instructional strategies and materials so teachers can be:

> "more systematic in their approach and kids, ultimately, are more successful… And each child is going to come up with things that work for him and her but if he doesn't even know what the key is and then he needs to look at the top of the graphic."

Multimodal Reading Materials are Needed to Expand Meaning-Making for BVI and Sighted Co-Readers (GC3).

People do not read in isolation and in some cases, the accessibility of content depends on it being accessible in multiple modalities. A blind advocate and educator noted,

> "One of the things I have noticed about working with families, over all of these years, with print Braille books, is if the kids cannot see the book and they can read the Braille, that is OK with them. However, the parents are not ok with it. They want to read with the kids, a lot of times they want to be able to help describe the pictures to the kids if the pictures are not described."

A sighted producer noted that designing materials for everyone's consumption is important, and noted,

> "It is no longer the exception that you see print in tactile maps, it is the rule. For example, in the UK packaging is in print and Braille. Beauty and functionality do not have to be at odds. Hopefully, we will see this everywhere."

A Foundational Tactile Graphicacy Curriculum is Missing (GC4).

Several members of the TAGS raised the issue that there is not a universal a set of tactile graphics, that have been robustly evaluated, and widely to teach the fundamentals of tactile literacy. An advocate, who is blind, attending the first TAGS shared this perspective:

> "We need a set of symbols in tactile graphics that is universally accepted. Besides that, we need a teaching method to say if you want to have a complex graphic, to say this is how you are going to go about it. As you say, have the simplified and then the complicated version. We need protocols and a curriculum."

Another BVI participant attending the first TAGS noted,

> "Blind kids can't process complex tactile information. If you create a graphic it better be really simple. And, you know, that is not the truth...it is about building for that learning curve. Building the scaffolding and education to build up what is a tactile graphic and how do you layer it. Just like a sighted child doesn't start with the final product, they spend years developing their visual literacy."

During the third TAGS, a TVI noted,

> "I do not think that we are that far from it [a standard set]. I think that is where is going to be the push for standardization because ultimately tactile graphics are used on the SAT or the ACT….I think that if you teach tactile graphics as a subject matter, you want to teach it in a systematic way...in school, you teach kids how to read maps the same as you teach them how to read Braille. There's a system to teach Braille, but to reach that point [with tactile graphicacy] you have to have some consistent materials to start with."

Finding and Getting Tactile Graphics and Illustrations into the Hands of BVI is Challenging (GC5).

The TAGS participants shared that it is difficult to find and then acquire graphics for tactile learners. Reporting on the Tactile Graphics Action Group's findings during the third TAGS, a TVI noted,

> "There are things available, but people just don't know where to go to look for them."

Another participant in this group reflected,

> "There is very little tactile content available all across the grades levels...right now they are focused in early grades—early elementary is where you have a lot of tactile books, but that does not extend to young adult and adult materials."

Similarly, after participating in the first TAGS Tactile Graphics Action Group breakout sessions, a TVI noted that one of the greatest challenges she encounters is that each state has its own policy in terms of getting tactile materials into toddlers hands,

> "At the New Jersey commission, in the early days we did work with children as young as a few months old, and we had TVIs who specialized in that. And then came along early intervention programs, and we were instructed that we could only have intermittent contact with young children...But at least we would have identified some of them, and we could share materials with them. That is a policy thing that varies by state or agency."

There is a Debate About the Need for Consistency versus Diversity in Materials and Experiences (GC6).

Throughout the TAGS, discussions emerged about the employment of tactile graphic design standards to ensure consistency in the ways concepts or information content is communicated. Several participants made comments indicating that consistency in the design of materials (and the production methods/materials used to produce the graphics) greatly impacts

their ability to read the graphic, and in turn the accessibility of the graphic. For example, during the third TAGS, a blind artist and teacher reflected on his experience with standardized tactile graphic materials:

> "When I was a kid growing up the symbol set was pretty well defined...we had some pretty consistent graphics stuff that we saw all the time because it only came from a single source...Nowadays anybody in the world with a Tiger embosser or something similar can make any bizarre design they want."

During a presentation on tactile graphics, a researcher who is BVI noted,

> "The maps were a little crappy, but they were consistently crappy. It might have taken you a couple of minutes to understand what the lexicon was in my maps, but once you figured it out, the system was pretty transparent."

On the other hand, other TAGS participants recognized the importance of having a diversity of graphics and graphical styles to ensure the accessibility of the content that was being represented. For example, a TVI reflected,

> "While it is essential to have a place to start with young children, students need to be able to progress to interpret a variety of symbols that represent the same concept."

Overemphasis on Visual Aesthetics in Tactile Graphic Design May Limit Accessibility (GC7).

TAGS participants noted that many tactile graphics are designed visually as opposed to tactilely, which greatly impacts the accessibility of a graphics. For example, regarding the design of tactile maps, a tactile graphics producer noted,

> "We [the TAGS participants] need to discuss, when is good enough, and when is 'beautiful' an obstacle to getting access to information that we need...There is a strong

> motivation to make maps look beautiful, but it is important not to cheat towards the beautiful. We need to focus on what functions under the finger."

Designers Often Do Not Pair the Correct Production Technology/Techniques to Their Design (GC8).

In addition to considering effects of the production methods and materials on the representation of information in a tactile form, the TAGS participants identified that the effectiveness of a graphic depends on the appropriate pairing between the production technology and way a designer has chosen to represent the information. An access technology specialist who is sighted argued that it is essential to develop design and production standards that correlate directly to specific production technologies:

> "We can create the symbol sets we want when we are using a particular tactile graphics embosser. A person would not be able to reproduce these reliably on Swell paper and even less reliably if you were using a low-resolution Braille embosser, standard Braille embosser for graphics."

A sighted designer and tactile media production technology developer attending the third TAGS explained that when you design a graphic…

> "you must consider the production method. With the Swell machine, you lose all of the detail, whereas with the vacuum machine there are layers of hierarchy."

A TVI noted how many people think that they can just use Swell paper for any graphic, stating that "just isn't true." A scientist who is blind noted that graphics that draw on visual perspective or tactile depth may not be easily perceived and understood if they produced using a raised line production technology.

Need for Protocol and Methods to Evaluate How Different Design Decisions/ Guidelines Impact Learnability of Graphics (GC9).

Throughout the TAGS participants noted that there has been little research conducted to evaluate how the application of the tactile graphics design guidelines, i.e. the BANA guidelines (Braille Authority of North America, 2010) impacts students learning. During the first TAGS, a tactile graphics producer noted,

> "To the best of my knowledge, there are few studies that have validated the BANA Guidelines, or other guidelines for that matter. As a community, we could focus on developing methods to assess graphics with students."

A tactile producer attending the third TAGS noted, "we do a lot of user testing but it is difficult to know what designs really help."

BVI Learners Need 3D Printed Materials (GC10).

During the discussions about tactile graphics, several participants who are blind discussed their interest in 3D printing as a tactile graphics production method. One of these participants, who regularly consults on the design of tactile science diagrams, noted,

> "I am very excited by the prospects of 3D printing because you need dimension for a lot of concepts."

Another participant noted that tactile graphics helped her succeed in science, but the lack of 3D models inhibited her from learning alongside her peers in laboratory settings. A computer science researcher who attended the second TAGS shared his objective to evolve 3D printing systems to

> "become a feasible means of production...so we can share them[tactile picture books] online to get more tactile books into kids hands."

A tactile graphic designer attending the second TAGS noted,

> "advancements in 3D printing technology has allowed him to build prototypes that are robust enough to touch."

IV. Issues Related to Tactile Graphics Design and Production

The Cost is Prohibitive in Tactile Graphic Production (GP1).

During the TAGS, the cost of creating tactile graphics and innovative tactile graphics technologies emerged as a factor impacting access to opportunities and resources for creating tactile graphics. During the first Symposium, an advocate who is BVI reflected about the trade-offs tactile graphics production houses need to make while designing materials. She noted that one such organization made a

> "recent decision to not include pictures due to cost."

When discussing the design features of a tactile illustration of a dog, a TAGS participant attending the second TAGS noted,

> "I mean, if you're going to make it thermaform, then it's really expensive to add those things on, but it might have been an interesting set out if the furry dog, the one who's supposed to be very furry if that one was actual texture from cloth."

A blind researcher attending the third TAGS noted one of the greatest challenges to developing a dynamic tactile graphics display is cost:

> "There are major costs to this approach and we are working to determine what the benefits of doing that would be."

Production Technologies are Often Overrated (GP2).

When discussing tactile graphics production technologies the TAGS participants cautioned that the affordances of new production technologies are often overstated and

overrated. A blind researcher noted, in regards to a tactile map design and production system he built,

> "it is important to know what the technical functionalities the system can achieve from the get go...you have to manage your expectations."

Several participants mentioned that the accessibility of 3D printed models is often diminished by the resolution of the prints, the texture of the materials, let alone the lack of consideration about what information is most useful to print in 3D.

Design and Production Technologies are Not Accessible (GP3).

When talking about the creation of tactile graphics, the participants noted that many design tools depend on graphical user interfaces are not accessible through the use of screen readers. For example, during the first TAG Symposium, a tactile graphics designer who is blind stated,

> "Any technical platform being used to create and distribute tactile materials should be accessible...especially new technical programs to improve the workflow of making tactile graphics."

During TAGS 3, a sighted producer led an impromptu activity to assess the accessibility of a command-based 3D modeling tool. Several TAGS participants who are BVI participated in the evaluation and found that there were several key factors that made the interface inaccessible, including the lack of ability to use the screen reader to access the menu options.

Disagreement about Standardization of Tactile Graphic Guidelines Divides Stakeholders (GP4).

The process of learning to design and produce tactile graphics can be greatly aided by existing design guidelines. However, during the TAGS, it became evident that there is a strong

debate as to whether there should be a codified set of tactile graphic designs. While there are formidable tactile graphic design guidelines, e.g. the Braille Authority of North America Tactile Graphics Guidelines (Braille Authority of North America, 2010), these do not dictate a set symbol set address the needs for specific content types. A blind artist, engineer, and researcher followed this up by making a claim:

> "Let the Standards Emerge because sometimes standards dampen creativity and give the impression that if you are following the guidelines, then you are doing it right. Not true."

When talking about tactile map design, another participant noted,

> "Each element on a map needs to be palpably different from each other, it is difficult not to use symbols that others have used to represent other elements. I am reluctant to call for codification when there are still so many variables, and things are still so fluid—still in play. I am not opposed to standards, but I do advise caution in locking things up when we are still trying to figure things out."

A sighted access technology specialist and an affiliate of BANA noted,

> "The guidelines and standards that are available are the standards for tactile graphics, but not necessarily for map making. It is more about where things should be placed, how things should be readable regarding lines and distances between objects, how to use lead lines to indicate if you are labeling something; it is not necessarily map related. There are not clear standards about how maps should be made."

There Are No Formalized Programs that Teach Tactile Graphic Design (GP5).

Many of the TAGS participants who engage in tactile graphic design shared that they learned how to create tactile graphics through trial and error, albeit yearned for more formal training or a community to support their practices. A producer attending TAGS 1 noted,

> "This event is exactly what I have been missing. I have had to learn on my own. It is nice that other people have gone through similar things, but how can we make it easier for others?"

A TVI attending the second TAGS reflected,

> "I never was taught how to design tactile graphics in school. Everything I have learned, I learned with students, and through comparing strategies with other teachers."

Table 4.6. Findings A: Issues Overview.

Issue Code	Issue
	Art Consumption by BVI
AC1	BVI Desire the Opportunity to be Consumers of Art.
AC2	A Lack of Consistency and Diversity of Accessible Art Affects BVI Consumption Experiences.
AC3	BVI Receive Unsolicited Attention when Being a Patron of the Arts.
AC4	Many Museums and Cultural Institutions Do Not view Tactile Art is Not Viewed As an Asset for All, Rather it is Seen as a Mandate or Something 'Special' for BVI.
AC5:	BVI Experience A Stigma When Touching Art.
AC6	Inaccessible Exhibit Configuration and Layout Inhibit BVI People from Accessing Art.
AC7	The Prevalence of Ineffective Labeling (on visual and tactile art) Affects the Accessibility of Art for People who are BVI.
AC8	Touch Affects Artistic Materials
AC9	BVI are not Exposed to Education focused on Touch-Based Art Interpretation.
AC10	BVI and Others Yearn for Opportunities to Discuss Touch-Based Art Interpretation.
AC11	No Universal Definition of Accessible and Tactile Art.
AC12	No Universal Vocabulary to Describe Tactile Art Expression and Experiences.
	Art Creation and Production
AP1	Being BVI Impacts One's Opportunity but not Desire/Need to Create.
AP2	Prohibition and Stigma of Touch Affect If and When BVI Create.
AP3	BVI Have to Overcome Being a Spectacle or Not Belonging when Publically Making Art.
AP4	BVI Desire, yet Miss Opportunities to Tactilely Observe in Art Studio Contexts.
AP5	Lack of Art Training for TVIs and Lack of TVI Training for Art Teachers.
AP6	BVI Need Opportunities to Be Teaching other BVI People.

Table 4.6. Findings A: Issues Overview.	
AP7	Lack of Access to Accessible Tools and Materials Inhibits BVI's Art Creation.
AP8	Many Tools and Materials Are Not Accessible To BVI.
Tactile Graphics Consumption	
GC1	Many BVI are Not Exposed to Tactile Graphics.
GC2	Tactile Graphics to Teach Math and Spatial Literacy are Very Limited.
GC3	Multimodal Reading Materials are Needed to Expand Meaning-Making for BVI and Sighted Co-Readers.
GC4	A Foundational Tactile Graphicacy Curriculum is Missing.
GC5	Finding and Getting Tactile Graphics and Illustrations into the Hands of BVI is Challenging.
GC6	There is a Debate About the Need for Consistency versus Diversity in Materials and Experiences.
GC7	Overemphasis on Visual Aesthetics in Tactile Graphic Design May Limit Accessibility.
GC8	Designers Often Do Not Pair the Correct Production Technology/Techniques to Their Design.
GC9	Need for Protocol and Methods to Evaluate How Different Design Decisions/ Guidelines Impact Learnability of Graphics.
GC10	BVI Learners Need 3D Printed Materials.
Tactile Graphics Design and Production	
GP1	The Cost is Prohibitive in Tactile Graphic Production.
GP2	Production Technologies are Often Overrated.
GP3	Design and Production Technologies are Not Accessible.
GP4	Disagreement about Standardization of Tactile Graphic Guidelines Divides Stakeholders.

Findings B: Strategies

The TAGS participants not only raised issues related to the consumption and production of tactile materials, they identified existing best practices and new strategies to improve the current state of access to materials and experiences and the accessibility of materials and experiences. In this findings section, we present an overview of the strategies that the TAGS participants suggested in relation to the issues areas specified in Findings A.

Importantly, in some instances, the strategies we identify are taken verbatim from participants. For example, during the first TAGS, a TVI noted: “tactile literacy is no different from building background for literacy.” She subsequently shared several strategies to get children engaged with tactile learning. She said, “TVIs and caregivers need to support children to co-design tactile experience stories. For example, if the child goes out finds objects and creates a narrative while the TVI/ caregiver can write the story just as the child just created it...the kid will relate to reading through their ego and what they have just experienced.” From this data, we identify the following strategy under the Structural Code Tactile Graphics Consumption: Train parents and other caregivers to create Concept books, a.k.a. Acorn Books or Sequence Books, to help students develop understanding about symbolic representation.

Some of the strategies emerged as a logical inference from the issue area. For example, under the Structural Code: Art Consumption, we heard one participant say “I was not worried about how long I stay there in the room. So I could just circle around and go onto the space that was a little less crowded….And I could circle back...and I had all that freedom...So it was really just a glorious experience to be able to look at something, and then can move on, and decide that you want to go back and look at that again because then you can rethink something.” From this description, we inferred that strategies are needed to train docents and other museum staff and patrons on how to work together with people who are BVI to craft their experiences; whereas some people may want formal guidance around an exhibit and work interdependently with a docent, others may want to explore the exhibit independently. There is not a one size fits all solution to making materials and environments accessible.

Art Consumption Strategies

Throughout the TAGS, the participants who are BVI recognized the ability of BVI people to create solutions to the issues that impact their everyday experience. Notably, an art educator who is blind noted, “Blind people have to take responsibility for ourselves. I always try to bring some curator gloves when I know I am going somewhere where I want to touch stuff. Then I can ask, and explain how I will not be transferring the oils from my hand.” During the introductions at the third TAGS, a professor of disability studies who is BVI shared her objective to “put forward the idea that blind artists should be the ones leading the way [in creating access to art].” The Accessible Museum Action Group who met during the third TAGS shared, “As blind people, we need to make ourselves available to work with museums to design programming to advance what they are doing if they are not doing anything already.”

In other instances, the strategies for improvement were proposed and/or directed towards museums and other cultural institutions. These strategies focused on suggestions to create inclusive museum exhibits and programs through the design of multi-sensory experiences and invitational art shows focused on tactile experiences. The participants also encouraged museum directors to “develop programming for museum staff—security to visitor services—to learn first hand about BVI’s experience of art,” e.g what information is lost after acquiring visual impairments, the affordances of touch and positioning, engage in collaborations with people who are BVI and BVI advocacy organizations. Furthermore, the TAGS participants suggested that museum curators focus on selecting pieces of art that demonstrated a diversity of materials and techniques, set exhibits up in a way that considers the proximity of a piece of work to objects and the spatial needed for a person to move around a piece (i.e. develop navigational guides that suggest how a BVI person can physically orient themselves to artworks), put tactile art pieces on

pedestals, and provide audio, Braille, and large print labels in close proximity and in ergonomic positions to the art pieces.

The TAGS participants also identified best-practices and strategies that TVIs/Rehabilitation/Independence Instructors can use to help their students access art. Their suggestions included reaching out to museum curators to identify existing exhibits that can easily be made accessible for students, contacting local NFB chairs to draw on their knowledge of blindness and resources, connecting with to local libraries for funding and settings where pop-up tactile art exhibits can be curated at low cost. The TAGS participants also noted that mainstream educators could work with students to develop accessible materials, e.g. the Build A Better Book Project ("Build a Better Book," n.d.).

Across all three TAGS, the participants consistently raised the issue of not having a tactile vocabulary to draw on to describe their experiences touching art and to ensure that another person has a common tactile reference point to their haptic experience. Accordingly, one of the strategies that they identified was to create a lexicon including 1) Vocabulary related to the affordances of materials—evoking emotion, evoking memory; 2) Vocabulary related to experience with materials—embodied, effective, ambiguity, movement, perspective, time; 3) Vocabulary related to design material characteristics—textures, temperature, weight, perspective. Furthermore, they indicated that a repository of tactile example and descriptions of worlds that describe visual concepts would be helpful.

Table 4.7. Art Consumption Strategies. AC1-Opportunities; AC2- Diversity; AC3- Attention; AC4- Mandate; AC5- Stigma; AC6- Layout; AC7- Labeling; AC8- Touch/Material; AC9- Art Education; AC10- Discuss Art; AC11- Definition; AC12- Vocabulary.

ID	Strategy												
People who are Blind													
1	Make ourselves available to work with museum curators	x		x	x	X	x	x		x	x	x	x
2	Take responsibility and demonstrate how to touch materials in ways that safeguard artworks.	x				x	x		X	x	x		
3	Share resources with different constituents about what works	x	x		x	x	x	X		x	x	x	x
4	Attend art education conferences and museum conferences, eg. American Alliance of Museums	x		x		X				x	x	x	x
Museums and Cultural Institutions													
5	Provide free admission to all tactile art shows that are curated for everybody; create an atmosphere of inclusivity.	x	x		x	X	x	x		x	x		
6	Curate of more immersive multi-sensory experiences that highlight the sense of touch.	X	x	x	x	x	x	x		x	x		
7	Curate juried/ invitational art shows to diversify the types of art that are available through the sense of touch.	x	X	x	x	x	x	x		x	x		
8	Include a diversity of styles and materials of art in their access tours.	x	X				x			x			
9	Develop programming for museum staff—security to visitor services—to learn first hand about BVI's experience of art, e.g what information is lost after acquiring visual impairments, the affordances of touch and positioning.	x			x	x		X		x	x	x	
10	Engage in collaborations	x			x	x		X		x			

Table 4.7. Art Consumption Strategies. AC1-Opportunities; AC2- Diversity; AC3- Attention; AC4- Mandate; AC5- Stigma; AC6- Layout; AC7- Labeling; AC8- Touch/Material; AC9- Art Education; AC10- Discuss Art; AC11- Definition; AC12- Vocabulary.

	with people who are BVI and BVI advocacy organizations.												
11	Create replicable and easily shared exhibits and programs	X									x		
12	Consider how a person's physical orientation to the artwork, e.g. how the artist intended the work to be viewed.	x	x	x		x	X			x	x		
13	Consider the proximity of a piece of work to objects and the spatial needed for a person to move around a piece, e.g. develop navigational guides that suggest how a BVI person can physically orient themselves to .	x					X			x	x		x
14	Put tactile art pieces on pedestals.	x					X			x			
15	Make sure that the tactile viewers are able to feel the art unabated by audio or Braille labels.							X			x		
16	Provide audio, Braille, and large print labels in close proximity to the art pieces.							X			x		
17	Provide Braille labels that can be read in an ergonomic position, e.g. horizontal (flat) or at a slight angle. For example, if attaching Braille labels to the wall, ensure that they are attached with a hinge so that people do not need to bend at the wrist.										x		
18	Support tactile artists to included accessibility specificities as part of their contracts with museums	X			x		x	x	x		x	x	x
Mainstream Educators													
19	Involve all students in	x			x	x	x	x		x	x	x	x

Table 4.7. Art Consumption Strategies. AC1-Opportunities; AC2- Diversity; AC3- Attention; AC4- Mandate; AC5- Stigma; AC6- Layout; AC7- Labeling; AC8- Touch/Material; AC9- Art Education; AC10- Discuss Art; AC11- Definition; AC12- Vocabulary.

	creating tactile artwork												
TVIs/Rehabilitation/Independence Instructors													
20	Contact museum curators to identify existing exhibits that can easily be made accessible for students.	x	x	x	X		x			x	x		
21	Contact local NFB chairs to draw on their knowledge of blindness and resources.	x			X	x					x	x	x
22	Connect with to local libraries for funding and settings where pop-up tactile art exhibits can be curated at low cost.	X	x		x	x	x			x	x		
23	Connect with local Makerspaces as sites where people can develop accessible materials for consumption.	X	x			x	x			x	x		
24	Advocate for getting continuing education credit for attending trainings in art education									x	x		
	Technology Developers												
25	Work with museums to create an application that shows the accessibility of museums or cultural works on platforms such as Google Maps.		x	x	x	x	X	x		x	x		
TAGS Participants													
26	Develop lexicon of tactile vocabulary, including three categories of terms regarding the interpretation of tactile artworks.							x		x		x	X
27	Develop tactile examples and descriptions of worlds that describe visual concepts.							x		x	x	x	X
28	Write an article directed towards museums making a case for tactile exhibits and guiding										X	x	x

Table 4.7. Art Consumption Strategies. AC1-Opportunities; AC2- Diversity; AC3- Attention; AC4- Mandate; AC5- Stigma; AC6- Layout; AC7- Labeling; AC8- Touch/Material; AC9- Art Education; AC10- Discuss Art; AC11- Definition; AC12- Vocabulary.													
	strategies												
29	Obtain the archive of accessible exhibits from the American Alliance of Museums										X	x	x

Art Creation and Production Strategies

Similar to the above comments on art consumption, the TAGS participants identified strategies that people who are BVI, TVIs and other educators, as well as the TAGS participant group, can focus on to increase and improve opportunities for BVI people to engage in art creation and production. The strategies that the TAGS participants identified clustered around the need to create new training programs for both TVIs and for people who are BVI that are interested in teaching and sharing their experiences. Regarding BVI leadership, one BVI artist and educator described his desire to create a special residency where people who are blind and deaf-blind can come together and learn in an environment where they feel free to explore and are not a spectacle for other people to be looking at. Others suggested that people who are BVI share strategies they have employed to overcome their fear of touching and exploring materials and their environments. Similarly, another suggestion was for BVI people to observe and share when touch has uniquely informed their creation process. The TAGS participants also identified a series of strategies that TVIs and other educators could use to support BVI art production practices. These included engaging in or creating professional development activities such as attending conferences and networking with other teachers. The TAGS participants also suggested that, at a bare minimum, TVIs should ensure that BVI students are provided with the same

materials and tools as the other students to create a sense of inclusion and then, if these are not accessible, identify workarounds so that the students can fully engage in the creative activity.

Table 4.8. Art Creation and Production Strategies. AP1- Agency; AP2- Stigma of Touch; AP3- Tactile Observe; AP4- Teacher Trainingl AP5- BVI Teachers; AP6- Access to Tools; AP7- Accessible Tools.

ID	Strategy	AP1	AP2	AP3	AP4	AP5	AP6	AP7
People Who are Blind								
30	Create residencies for blind and deaf-blind artists to explore how to look at things through the sense of touch and learn skills.		X	x		x	x	
31	Share personal experiences where the sense of touch has aided their creative projects.					X	x	
32	Share strategies used to overcome the stigma associated with touch. [The opportunity for a "person to figure out access points for themselves is so important for them to develop their own their art practice."					X		
TVI and Mainstream Educators								
33	Provide BVI students with the same tools/materials as all students; in cases when these tools are not accessible augment the materials/tools so they can perform the same task or achieve similar results.			x		x	X	
34	TVIs should connect with art teachers in their schools and districts and vice versa.				X			
35	TVIs should attend art conferences, and art teachers should attend TVI				X			

Table 4.8. Art Creation and Production Strategies. AP1- Agency; AP2- Stigma of Touch; AP3- Tactile Observe; AP4- Teacher Trainingl AP5- BVI Teachers; AP6- Access to Tools; AP7- Accessible Tools.								
	conferences.							
TAGS Participants								
36	Establish local tactile art clubs	x	X	x	x	x		
37	Create and promote training opportunities for TVI about accessible art education, e.g. training of the trainer.				X			
38	Create videos of blind artists talking about their creative processes and the materials they use.					X		
39	Write up successful tactile making activities.				X			
40	Develop and disseminate tactile/ accessible art lessons plans to parents and caregivers.				X			

Finally, the TAGS participants identified several action items for the TAGS participants, which aligned with the aforementioned strategies. These included establishing a network of tactile art clubs where BVI people and other interested parties can share their artwork and engage in art creation together. Another suggestion included creating videos of blind artists talking about their creative processes and the materials they use as a way to become role models for other BVI. The TAGS participants also encouraged each other to be diligent in writing-up and discriminating [disseminating?] successful inclusive tactile making activities, and further, to create lesson plans for parents and caregivers.

Tactile Graphics Consumption Strategies

Unlike the suggestions related to tactile art consumption and production, the TAGS participants did not identify specific audiences for their suggestions. Rather, most suggestions focused on activities that the TAGS participants themselves could engage in, many of which directly related to the development of curriculum to support tactile reading and the identification and distribution of materials to support different curriculum. Generally, the participants focused on developing a tactile literacy curriculum that covers three foundational skills: 1) how to touch materials, 2) how to set-up one's space and orient oneself to the learning environment, 3) how to understand proportions through touch, and 4) how to understand representation and likeness. The suggestions pertaining to identification and distribution of materials centered on creating a comprehensive matrix or framework that identifies students learning needs at different ages and the current materials available to teach these skills. This suggestion is well paired with the suggestion for creating a standard set of tactile graphics/items for each grade level that are connected to standards that students need to achieve. The TAGS participants also recognized that creating such resources will require evaluation of the designs. Accordingly, they suggested working with national organizations who help fund the production of such graphics.

Table 4.9. Tactile Graphics Consumption Strategies. GC1- Exposure; GC2- Tactiles 4 Math; GC3- Multimodal; GC4- Curriculum; GC5- Distribution; GC6- Consistency; GC7- Aesthetics; GC8- Pairing Tech/Design; GC9- Evaluate; GC10- 3D Printed**.**

ID	Strategy	GC1	GC2	GC3	GC4	GC5	GC6	GC7	GC8	GC9	GC10
TAGS Participants											
41	Create a tactile matrix that specifies the sources of tactile materials for different age groups	x			x	X				x	

Table 4.9. Tactile Graphics Consumption Strategies. GC1- Exposure; GC2- Tactiles 4 Math; GC3- Multimodal; GC4- Curriculum; GC5- Distribution; GC6- Consistency; GC7- Aesthetics; GC8- Pairing Tech/Design; GC9- Evaluate; GC10- 3D Printed**.**											
42	Create a set of tactile graphics/items for each grade level that are connected to standards that students need to achieve, and identify the publishers of those material				x	X				x	
43	Encourage parents of BVI students to the NOPBC meetings as a way to distribute information about materials	x			x	X					
44	Develop teaching and learning strategies to teach BVI about: 1) how to touch materials, 2) how to set-up ones space and orient oneself to the learning environment, 3) how to understand proportions through touch, and 4) how to understand representation and likeness				X						
45	NFB work with AAF to get people testing tactile graphics									X	
46	Present the need for tactile art materials and instruction at conferences for art educators				X						
47	Create platforms to share strategies that get children engaged with tactile learning, e.g. Narrating and describing, creating concept books, creating experience stories, providing supplies and teaching access				X						

Table 4.9. Tactile Graphics Consumption Strategies. GC1- Exposure; GC2- Tactiles 4 Math; GC3- Multimodal; GC4- Curriculum; GC5- Distribution; GC6- Consistency; GC7- Aesthetics; GC8- Pairing Tech/Design; GC9- Evaluate; GC10- 3D Printed.											
48	Identify each states' policy on how to identify blind children in order to enhance the distribution of resources					X					
49	Support the Early Explorers programs				X						

Tactile Graphics Design and Production Strategies

The TAGS participants identified the cost of production, the inaccessibility of production technologies, the ongoing debate about whether tactile graphics design should be standardized, and the lack of formal tactile graphics design training opportunities as factors that all affect the state of tactile media and inclusive education. Their suggestions for addressing these issues focused on forming a group to conduct accessibility evaluations of existing tactile graphics production technologies, creating and funding drawing kits for kids and their families so that tactile design becomes part of their skill set at an early age, creating a list of guiding questions for designers/producers (as opposed to standards or guidelines), and generally engaging in the promotion of and design of access-focused design in mainstream learning environments.

Table 4.10. Tactile Graphics Production Strategies. GP1- Cost; GP2- Inaccessible; GP3- Standardization; GP4- Design Education.					
ID	Strategy	GP1	GP2	GP3	GP4
TAGS Participants					
50	Create a list of accessible production technologies		X		
51	Create a working group to investigate accessible technology and distribute information		X		
52	Develop a tool kit for engaging kids in tactile graphics at an early age. Start early and often.	x	X		x
53	Fundraising goal of $250,000 to deliver supplies to 1000 school aged blind children, as a first step to reaching the	X			x

Table 4.10. Tactile Graphics Production Strategies. GP1- Cost; GP2- Inaccessible; GP3- Standardization; GP4- Design Education.					
	60,000 children in need of these supplies.				
54	More training opportunities K-12 art teachers about accessible/ universal design.				X
55	Refine and distribute guiding design questions to accessible content designers/ curators:			x	X

Strategies and Action Items to Formalize the TAGS Community

In addition to strategies affiliated with each of the Structural Code categories, including the related action items they identified for themselves, the TAGS participants identified a series of strategies to create an organizational structure that would support ongoing engagement of the TAGS participants and build a network of other interested stakeholders. Across the TAGS, the participants recognized that collectively could identify and refine a mission statement and goals. During the first TAGS, an "Action Item" group suggested the mission of the TAGS group,

> "To build and maintain a community of practice so tactile matter experts can enhance and disseminate their practices (including supporting the supply development) pipeline; to conduct outreach so that consumers and educators who are researching non-visual approaches to STEAM tasks can discover effective strategies and the community of practices; and to ensure that developers of new tools and techniques of tactile representations have an opportunity to connect with experts and mentors in the community of practice."

Furthermore, the group identified the categories of strategies that would guide future action: 1) support efforts to make tactile art, make a tactile art market, and support opportunities for exhibition; 2) identify a system approach to getting tactile graphics, arts, and other materials into the hands of all BVI children, 3) support the families of blind children, 4) support blind people to make their own tactile materials, 5) support this community network, create awareness of tactile

literacy, create opportunities, and build organization. Throughout the second and third TAGS, these issues resurfaced. Several specific strategies included: develop a social media presence, hold a recurring TAGS annual meeting, create a professional membership designation for TAGS involvement, connect with other working groups such as the Benetech 2D/3D working group and the Museum Access Consortium.

Discussion

The RPP team designed and implemented the TAGS with the intention that a variety of stakeholders[24] could come together in a forum to discuss the state of tactile art and graphics consumption and production for individuals who are BVI, and their experiences of engaging in these practices. As mentioned earlier, the aim of the study was to address three research questions, focused on identifying the 1) factors/issues that impact the participants' art and graphics consumption, production, and instructional practices, 2) the strategies that the participants identify to resolve or address such factors/issues, and 3) underlying problems of practice impacting tactile media consumption and production. In the findings section above we provided evidence to address the first two questions.

It is important to note that by focusing on these issues in our analysis of the data, we overlooked the TAGS participants' celebration of tactile art and tactile graphics and other accessible experiences. For example, during the third TAGS, the participants enthusiastically shared the "Random Acts of Access" they had experienced. Random acts of access is a phrase defined by Kleege (2018) to describe instances when people who are BVI are granted permission to touch artifacts in museums and other cultural institutions (Kleege, 2018). One BVI participant shared:

[24] Access Tech Specialist, Advocats, Artists, Art Educators, Designers, Museum Curators Rehabilitation. Educators, Science Researchers, Social Researchers, Technology Researchers, TVI Educators, etc .

> "I was on my honeymoon. I was in Paris, and I was going to Notre Dame. You are walking through, around, behind the altar. Then, you went upstairs, on top of the balcony, where all the gargoyles are. We were the last people on the tour. By the time we got to the middle of the top of the outside balcony, where all the gargoyles are, all of a sudden, my wife and I started hearing these security guards with walkie-talkies surrounding us. She was like, 'What's going on here?', this woman tries to articulate to us in French, 'Stay here, don't go anywhere.' All of a sudden, we start seeing the rest of the line move outside, away from us. Now, we are isolated with these security guards flanking us on either side, and we still don't know what the hell is going on. This woman finally says, 'Come on this way. Follow us.' She starts walking us towards this narrow set of stairs. It is like this wooden structure, that is really narrow and really tiny. I am ducking my way through, and I am listening to everything that she is saying because I still don't know what's going on. Then [my wife] said 'Oh my God, they are taking us to the bell."

The TAGS participants also celebrated the sense of touch as a tremendous resource and vehicle for exploring the world. During the first TAGS, a BVI participant reflected that her art practice emerged because of her parents' encouragement of tactile exploration.

> "I have always been and always was encouraged to get lots of hands-on experience. I am so thankful for this"

The TAGS participants also provoked one another to think critically about touch. As a sighted tactile artist reflected,

> "We tend to think of touch as fingers touching a surface, but we might expand what that ...it means that your whole body is involved that you are moving, it means that you are emotionally engaged. To expand the meaning—beyond fingers touching."

A BVI participant expressed,

> "For me to experience tactile art is obviously, not looking at it [laughter], but to try to use both of your hands and listen to what your fingers are telling you—you might not be used to doing that, but there is a real opportunity there."

As evidenced by these quotes, the TAGS event became a forum where practitioners and scholars who consume, produce, and instruct with tactile media came together and discussed the issues that impact their practices, compared experiences, and envisioned solutions. In some instances, the issues that the participants shared emerged as a result of participating in the TAGS. For example, when describing her experience of art within the TAGS art gallery, one participant noted,

> "There wasn't anybody watching me over my shoulder...I wasn't worried about how long I stay there in the room...It was really just a glorious experience to be able to look at something, and then can move on, and decide that you want to go back and look without fear of being judged."

In this instance, the participant was comparing what she experienced at the TAGS to what she had experienced in other museums. The activity provided her with an opportunity to reflect on her prior experiences. In other instances, the participants shared stories of experiences that occurred outside of the TAGS without being prompted by a direct experience with materials presented at the TAGS. For example, many participants shared the Random Acts of Access the experienced without reference to the tactile art gallery.

Regardless of the source of a person's experience and insight, the data that emerged during the TAGS confirmed our initial conjecture: people who are BVI consistently encounter barriers that limit their opportunities to consume and create art generally, as well as tactile art

and graphics. Throughout the TAGS, participants shared that opportunities to be consumers of art (AC1) and tactile graphics (GC1, GC2) are very limited. Similarly, we learned that the dearth of opportunities to engage in the production of tactile media is a concern of the TAGS participants—BVI and sighted alike. For example, we found that it is rare for people who are BVI to engage in studio art experiences (AP4), or tactile graphics production (except for in the role of evaluator of created materials).

In addition to confirming our initial conjecture, our analysis of the data revealed a series of factors/issues that the TAGS participants reported encountering when trying to access art and graphics or to produce these materials, as well as the solutions they identified to overcome these issues. Many of these issues are not novel to the TAGS participants or to the Access Computing community. However, having a meta, ecosystem view of these issues allows us to identify the problems of practice regarding tactile media that cause barriers and perpetuate exclusion of people who are BVI from full participation in our media and information landscape, and examine how the strategies proposed by the TAGS participants can get to the core of such problems. That is, we can address our third research question, What do the factors/issues and strategies reveal about the problems of practice related to tactile media that the TAGS participants and in turn similar stakeholders encounter?) Furthermore, we identify and propose new recommendations to guide the ASSETS community in future work related to the design of systems to support BVI people's inclusion in art and graphics consumption and production.

Problems of Practice

We identify five interrelated problems of practice: 1) Belonging and Conspicuousness; 2) Touch as Deviance; 3) Inadequate Educational Programming; 4) Nascency in Tactile Design and Representation; 5) Access To vs. Accessibility Of. In this section, we describe the problems of

practice and provide the issue and solution areas that led us to each of these problems of practice. Under each problem of practice we also discuss the following matters.

A. **Tactile Graphics vs Tactile Art:** We consider if and how these problems of practice are common across all formats of tactile media, while taking note of which considerations are specific to tactile art/accessible art versus tactile graphics;
B. **Tactile Media Literacy Specific:** We discuss if and how these are problems that are related to BVI peoples' experiences of tactile media alone, or are more broadly experienced in their lives.
C. **Related Literature**: We examine how the problem of practice has previously been approached by education, design, museum studies, and HCI literature.
D. **Design Opportunities: We explore** opportunities for the ASSETS community to address some of these problems of practice, alongside relevant socio-technical design principles

Problems of Practice Descriptions

1) Belonging vs. Conspicuousness

We contend that the experiences of not belonging or having a place at the table in media consumption and production is a fundamental concern that impacts progress within the field of tactile media, as it does many other spheres of public life. At the same time, tactile media (both art and graphics) consumption and production are activities through which a sense of belonging can be established when people who are BVI are included. Baumeister and Leary (2017) explain that the need to belong is a fundamental human motivation and takes precedence over self-esteem and self-actualization and that individuals working alone face a "severe competitive disadvantage" compared to those working as part of a group (Baumeister & Leary, 2017, p. 499). Being singled out as different or being treated as other—as many people with disabilities have

been—impacts an inclusive and equitable society as well as one's sense of belonging. It is well established that many people who are BVI experience a range of psychosocial experiences related to their visual impairments (Lindo & Nordholm, 1999), including not feeling a sense of belonging or inclusion in museums (Fielder, 2000; Kleege, 2018) as well as other environments, e.g. (Gold, Shaw, & Wolffe, 2010; Jessup, Bundy, Broom, & Hancock, 2017; Papakonstantinou & Papadopoulos, 2010).

During the TAGS, we learned that the lack of opportunities for people who are BVI to engage in media consumption or production, and the feeling of conspicuousness when they do engage in such activities (AP3, AC3), impacts their sense of belonging. The TAGS participants attributed their sense of conspicuousness to other people's curiosity, museums professionals' lack of preparedness to support blind visitors, and/or being positioned as "others" (AC4), and not always knowing how to position themselves in relation to objects or physical phenomena.

One TAGS-identified strategy to offset the burden of not belonging or the sense of conspicuousness centered on a preventative measure: the creation of an accessible mobile application that helps people who are BVI find museums and cultural institutions with accessible materials (Strategy 4 in **Table 4.7**). In this way, people who are BVI would not find themselves in non-inclusive and isolating experiences. This strategy does not strive to augment a person's social experience while engaging with tactile media but helps guide a person to places where they have a greater sense of belonging. All the while, the participants were hesitant to create a concrete definition of "tactile art;" creating such a distinction could unnecessarily differentiate individuals who are BVI from sighted individuals, i.e. "Do we actually need to know that it is tactile art? A sighted person can still look at it and if there are tactile and haptic aspects to it that are wonderful (AC3)."

Many of the strategies that the TAGS participants identified to increase a sense of belonging in art consumption focused on creating scenarios through which people who are BVI and museum curators could work together to share knowledge and experiences to address issues that limit their access to content and the accessibility of that content (Strategies 1, 2, 3, 5, 7, 8, 10, 11, 12, 15). These strategies are consistent with a recent trend to involve people who are blind or visually impaired in the museum exhibit design process (Chick, 2017; Rector, Salmon, Thornton, Joshi, & Morris, 2017; Wilson et al., 2017), and parallel more general suggestions for how to make original artistic and informational content accessible (e.g., provision of tactile and audio materials, trained museum staff, special museum programs, and navigable spaces) (Argyropoulos & Kanari, 2015; Gallego & Núñez, 2014; Guarini, 2015; Manship & Hatzidimitriadou, 2015).

The TAGS participants identified two strategies focused on creating a sense of belonging for people who are BVI who are interested in creating art: establishment of residencies for blind and deaf-blind artists to explore how to look at things through the sense of touch and learn handcraft skills (Strategy 30) and establishment of local tactile art clubs where BVI and sighted people can come together to make tactile art (Strategy 36).

The problem of practice we titled "belonging and conspicuousness" emerged most prominently in the data around the BVI peoples' art consumption and production practices. While the problem of practice did not explicitly appear in our data pertaining to tactile graphics, we believe that it affects art and graphics consumption and production alike[25].

[25] Our thoughts about why this problem of practice did not emerge in our data set involve several factors. First, we did not reach saturation in our data collection. Second, we did not create exhibits with tactile graphics (as we did tactile art exhibits). Third, few museums have tactile graphics available. Fourth, reading of tactile graphics often occurs in more private educational settings. Fifth, many people have not been positioned to be the creators of tactile graphics.

Based on our findings, as well as findings from the aforementioned scholars, we have come to see accessible exhibits' tactile media as boundary objects through which people with different abilities and interests can come together and establish a sense of belonging. As Star (2010) accounts, "Boundary objects are essentially organic infrastructures that have arisen due to what Jim Griesemer and I called ''information needs'' and allow different groups to work together (Leigh Star, 2010, p. 602)."

Accordingly, to help address the problem of practice "Belonging and Conspicuousness" we share three recommendations to guide ASSETS researchers' (and others') future work in regards to tactile media:

A. Identify the tensions that arise when creating accessible/ tactile art, exhibits, and programs that fully included people who are BVI in experiences. For example, consider how the placement of accessible materials and experiences may create a sense of conspicuousness for blind patrons.
B. Treat accessible exhibits and tactile media as boundary objects that provide an infrastructure through which diverse stakeholders can converge and collaborate, and spaces and cultures can transform.
C. Consider whether the tactile-media focused technologies we develop take into account the psychosocial aspects of the end-users' experiences and whether they entice a sense of belonging or perpetuate conspicuousness in media consumption and production. While Principle B is a well established consideration in the selection of and deployment of assistive technologies e.g. (Scherer, Craddock, & Mackeogh, 2011; Scherer, Sax, Vanbiervliet, Cushman, & Scherer, 2005), current work on art accessibility e.g. (Asakawa et al., 2018; Kyle et al., 2017) and tactile media design within the ASSETS

community has not explored belonging or conspicuousness directly in regards to tactile media consumption or production.

2) Touch as a Form of Deviance and Source of Social Stigma

For some BVI individuals, the fear of being observed as not belonging while engaging in art creation and consumption was attributed to experiences that the TAGS participants named as the "stigma of touch". While the comments about the social stigma of touch most prominently emerged during the discussions about art consumption in public places (AC5) and art production (AP2), the topic of overcoming the stigma of touch and being able to freely explore one's environment and draw on touch-based information gathering emerged throughout all of the TAGS activities.

The TAGS participants' experience and awareness of the stigma of touch is a recognized social phenomenon. Generally, the term 'stigma' refers to any persistent trait of an individual or group which evokes negative or punitive responses; disabling conditions are stigmatizing to the extent that they evoke negative or punitive responses (Susman, 1994, p. 16). Goffman (1963), one of the pioneers of stigma research, noted that "[Stigma is] an attribute that links a person to an undesirable stereotype, leading other people to reduce the bearer from a whole and usual person to a tainted, discounted one." (Goffman & Goffman, 1963). He elaborates that stigma is best explained by reference to the notion of deviance, i.e. deviation from prevalent or valued norms. Importantly, he demonstrates that deviance is not an inherent property and, in effect, a person is not a deviant until his acts or attributes are perceived as negatively different.

In this case of the TAGS, the participants shared their experience that society views touch as a deviant from the norm. To this point, Pallasmaa (2012) explains that in western cultures touch and tactility have historically been passed over in many fields since vision is regarded as

the “noblest of the senses” (Pallasmaa, 2012, p. 15). Jehoel et al. (2006) note that research in psychology (perceptual and cognitive) is predominantly centered on visual and auditory information processing, not tactile perception and cognition for teaching and learning (Jehoel, McCallum, Rowell, & Ungar, 2006). Candlin explains the complicated relationship between BVI people’s desires to touch materials in museums versus the desire to preserve artifacts (Candlin, 2004), an issue also raised by the TAGS participants (AC8).

In a recent effort to bring more attention to touch, Kleege (2018) provides a critique of how visual art and blindness are linked in many facets of culture and contests the notion that viewing art involves sight alone (Kleege, 2018). Candlin (2003) pleads for an art education that starts from tactile sensations (e.g., the tactility of art, its texture, its weight, etc.) and criticises the focus on vision in art education: He suggests that there should be “an art for the blind that is as separate and different to the art for the sighted (Candlin, 2003).” Penketh (2014) takes a critical lens on the dearth of art education for the blind, and suggests that critical social pedagogies that have been applied to “work relating to gender, race, and class should be extended to disability in order to promote critical engagement through art education rather than critical avoidance (Penketh, 2014).”

While the stigma of touch is a recognized phenomenon, the TAGS participants only shared one specific strategy aimed at addressing the stigma of touch, though many of the strategies described under the Belonging and Conspicuousness Problem of Practice also apply to stigma of touch: Developing educational programs that involve all students in creating tactile media (Strategy 19) and thus increasing exposure to the value of touch.

While the notion of stigma has been addressed in relation to the use of assistive technologies by the ASSETS community (Koelle et al., 2018; Profita et al., 2018; Shinohara &

Wobbrock, 2011), to the best of our knowledge few if any efforts have been made to explicitly investigate how and when the stigma of touch impacts how people who are BVI engage in tactile media practices, and in turn, how to device socio-technical strategies to reframe touch away from deviance into a universal avenue for engagement. By defining touch as a form of deviance and source of social stigma as a problem of practice, we highlight the fact that there needs to be a multipronged approach to address the stigma of touch as it applies to tactile media consumption and production.

As a first step, the TAGS community and the broader ASSETS/ HCI community can conduct additional empirical investigations to verify and expand upon these findings with a larger participant group. We can then look to the tangible and embodied interaction community (TEI) and haptics design communities to assess whether existing tactile and haptic technologies have already been developed to create new touch-based interaction methods that also transform social attitudes about touch. We can also start to look to the emergent body of literature from museum studies, which is increasingly recognizing how conceptual ideas about touch introduce barriers to inclusive experiences, e.g. (Papadimitriou, Plati, Markou, & Catapoti, 2016). We can also start to draw on the emergent literature focused on: 1) creating spaces that set a different expectation for one's touch-based encounters with objects, e.g. (Maerker, 2015), 2) the need of touch-based access over preservation, e.g. (Baccaglini, 2018), and 3) new approaches to prioritize touch as interpretive resource (Christidou & Pierroux, 2019; d'Evie & Kleege, 2018; Vaz, Fernandes, & Rocha Veiga, 2018).

3) Inadequate Educational Programming, Media Supply and Dissemination of Existing Learning Materials

The TAGS participants recognized that educational experiences focused on preparing people who are BVI to be consumers of tactile media do not meet their needs—either as learners

or teachers. Similarly, the TAGS participants recognized that educational experiences focused on preparing people who are BVI to be creators of tactile media do not meet their needs. Many of the strategies that the TAGS participants identified to alleviate the inadequacy of educational programming focused on tactile literacy education and are common across all practices, including the tracking down of existing resources (Strategies 34, 35, 41, 42, 43, 48) and spending the time to document and share lived practices (Strategies 39, 40, 44, 46, 55). All the while, there are important differences between each practice area. Accordingly, we address each practice separately in this section to highlight the nuance between the needed teaching practices and materials.

3a: Education for Art Consumption

The TAGS participants (sighted and BVI) shared that they desire, yet are rarely exposed to, educational opportunities and resources to support touch-based art interpretation (AC9, 12). These findings are congruent with the work of scholars who have provided empirical evidence that people who are blind or visually impaired are interested and very able to engage in art consumption when appropriate access measures are provided (Carpio, Amérigo, & Durán, 2017; Hayhoe, 2008, 2017; Kleege, 2010, 2018). Of note, Hayhoe, a disabilities studies and education scholar, describes the lack of such resources as passive exclusion of people from art education (Hayhoe, 2008, 2017). One such form of passive exclusion is the lack of artistic materials that are accessible and little diversity of content (AC2).

To address the issues related to education for art consumption, the TAGS participants suggested that practitioners engaged in tactile interpretation should develop and evaluate a lexicon of tactile vocabulary, including three categories of terms regarding the interpretation of tactile artworks (Strategy 26), along with developing a collection of tactile examples and

descriptions that describe visual concepts (Strategy 27). In a recent study, Carpio et.al (2017) evaluated the ability of BVI students to develop an aesthetic appreciation of artworks when they are taught tactilely while being described through verbal description of the content and sounds from the scenes and music from the artistic period. They found no significant differences between blind and sighted peers in content acquisition or aesthetic appreciation of the images (Carpio et al., 2017).

While the TAGS participants identified, like Carpio, that the use of targeted vocabulary and sound made art consumption experiences more effective for people who are BVI, they did not specifically reference other strategies identified in existing scholarship. One possible source for developing inclusive programming focused on art consumption is Coster et. al's (2004) framework for engaging BVI museum visitors in art interpretation. They suggest: Providing individual art instruction responsive to each student's unique socio-cultural, experiential, and visual perspectives; connecting tactile experiences of an art piece back to the visual attributes of the original artwork; and providing opportunities for dialogue between an instructor and the student, where touch and vision are used in dialogue to construct meaning from the art piece (Coster & Loots, 2004). Employment of such strategies may help the TAGS participants and others to develop programs to train TVIs in art interpretation, create a frameworks through which teachers can get continuing education credit for attending training in art education (Strategy 24), and create a museum design certificate programs for museum professionals focused on access and accessibility.

Regardless if there are documented resources to support inclusive art consumption, the TAGS participants did not reference such strategies. This suggests an opportunity for the development of teaching and learning platforms and materials guided by the following

requirements: 1) use of a defined and shared tactile vocabulary set, with examples of each concept in forms that are tactilely meaningful and can be linked to a range of visual metaphors or representational styles; 2) individualized learning paths based on a person's sociocultural, experiential, and visual perspectives; 3) prompts to support critical inquiry into a piece of artwork (such as those used in the Denver Art Museums Art Fitness 101 curriculum); and 4) development of a protocol to evaluate the effectiveness of such strategies. This represents a new opportunity for the ASSETS community.

3b.Education for Art Production

In relation to art production, the TAGS participants who are TVIs shared that they are not trained in how to support their BVI students in creating art and that many mainstream art teachers are not familiar with strategies used to support BVI peoples' learning (AP5). During the third TAGS, the BVI participants were thrilled by the opportunity and future prospects of learning to create art from another BVI artist; in large part because they recognized that there are few such teaching and learning environments that support this type of interaction (AP6). Furthermore, the TAGS participants noted that there are few accessible design tools available (AP7). In response, the TAGS participants advocated that TVIs attend art conferences and that art teachers attend TVI conferences (Strategy 35) and meet regularly in their local school districts (Strategy 34) or through the local tactile art clubs (Strategy 36). In addition, the TAGS participants emphasized the need for teachers to write about and disseminate their successful tactile making activities (Strategies 39 and 40).

Unlike the area of education for art consumption, to the best of our knowledge, there are few documented and evaluated instructional resources that can be drawn on to support art instruction for, with, and by people who are BVI. Axel and Levent's (2003) seminal book, Art

Beyond Sight, is one of the few resources available. In this book, the authors strongly advocate for cultural programs that involve people who are blind or visually impaired in artistic media creation and production. However, like many publications about art education for the blind, this book does not provide any concrete pedagogical suggestions. They only go so far as to describe the context of teaching experiences and offers a list of accessible tactile media creation materials, i.e. clay, paper mache, etc.

Scholars in the field of HCI have only recently begun to examine art/ creativity education for people who are BVI. Notably, Bennett has developed a toolkit for facilitating accessible design workshops with blind people (Bennett, 2018), but no concrete pedagogical resources have been developed based on this work. Lazar et al. (2018) have looked to art therapy as a theoretical lens to examine and design making experiences (Lazar, Feuston, Edasis, & Piper, 2018), but this does not address the unique needs of people who are BVI. Others have started to look at the design of tools and systems that support people who are BVI to be creators of tactile graphics and other graphical information(Forsslund & Ioannou, 2012; Kurze, 1996; Suzuki et al., 2017). However, there are few studies in the HCI community that have evaluated the art and graphics production strategies of people who are BVI and developed tools to support these practices.

The Do It Yourself Assistive Technology Maker movement aims to engage people with disabilities in the production of their own assistive technologies or other media (Buehler et al., 2015; Hamidi & Baljko, 2015; Hook, Verbaan, Durrant, Olivier, & Wright, 2014). However, these efforts do not provide robust instructional resources or directly focus on inclusive art instruction or strategies for how to make art and design tools and materials more accessible.

Our research, as well as this emerging literature, is illuminating the opportunity to engage in socio-technical research efforts to design, implement, evaluate, and disseminate inclusive art creation and production focused curriculum, creativity-support tools, etc. We suspect that by drawing on Universal Design for Learning (UDL) principles (e.g including alternatives that make the learning accessible and applicable to students with different backgrounds, learning styles, abilities, and disabilities (Rose, 2000), will aid this process. The "universal" in Universal Design for Learning does not imply a single solution for everyone, but rather it underscores the need for inherently flexible, customizable content, assignments, and activities. Flexibility is essential for two reasons: (a) individual differences between learners and (b) differences between instructional media (Glass, Meyer, & Rose, 2013).

3c. Education for Tactile Graphics Consumption (Tactile Literacy)

The TAGS participants shared that tactile graphics education is similarly inadequate. The TAGS participants shared that a lack of tactile graphics and multimodal materials available for educators to use during early reading (GC3), math instruction (GC2), and more generally in academic subjects (GC5, GC10), impacts their abilities to teach touch-based interaction with materials and tactile literacy. Furthermore, the TAGS participants indicated that they are in need of a foundational tactile graphicacy curriculum to support people in developing the techniques and confidence to read tactile graphics and progress from basic concepts such as shapes to more complicated representations of data found in STEM graphics (GC4). The participants' experiences are reflective of recent studies that have found that there is a need for curricular materials and guidelines to support teachers of visually impaired students in graphics literacy instruction beginning in the early grades (Rosenblum, Cheng, & Beal, 2018). Students who are BVI often do not develop the skills to efficiently and accurately access graphical information

(Beal & Rosenblum, 2018). Furthermore, our findings concur with Zebehazy & Wilton (2014) who found that the biggest issue for most TVIs is that their students had not received explicit instruction in using graphics (Zebehazy & Wilton, 2014).

To address this issue, the TAGS participants recommended the creation of a set of tactile graphics for each grade level that are connected to standards that students need to achieve with links to the publishers of those materials (Strategy 42). In addition, they recommended creating a tactile matrix that specifies the sources of tactile materials for different age groups (Strategy 41). Other suggestions focused on the specifics of what a curriculum should include. For example, Strategy 44 suggested focusing on 1) how to touch materials, 2) how to set-up one's space and orient oneself to the learning environment, 3) how to understand proportions through touch, and 4) how to understand representation and likeness.

More generally, the TAGS participants suggested creating platforms where teachers could share their effective teaching strategies (Strategy 47) and learn about each state's policy on how to identify blind children in order to enhance the distribution of resources (Strategy 48). This represents a new opportunity for the ASSETS community.

3d. Education for Tactile Graphics Production

The tactile designers attending the TAGS similarly reflected that there are no formalized programs that teach tactile graphic design to sighted or BVI designers (GP4). To this point, the TAGS participants referred to the Guidelines and Standards for Tactile Graphics (Braille Authority of North America, 2010) but noted that these guidelines are not enough, which concurs with Rosenblum et al.'s (2018) findings; "there are no guidelines for teachers of visually impaired students on how to introduce graphics to their students or how to teach them the systematic use of graphics as tools to gather information, nor are there guidelines on preparing

graphics for visually impaired print readers (Rosenblum et al., 2018, p. 476).” While the TAGS participants did not develop guidelines on preparing graphics for visually impaired print readers, they did develop a list of questions to support designers in their creation processes (Strategy 55). This resource builds on efforts such as the tactile graphics decision tree, developed by Touch Graphics, Inc., for choosing which print images need tactile representations and which need descriptions, or both (“Image Sorting Tool,” n.d.). However, as discussed below in the section related to the problem of practice titled “Design Considerations for Communication/ Representation of Content and Experience”, there are many unevaluated and unresolved design guidelines.

In addition to the lack of formalized programs that teach tactile graphic design, many tactile graphics design and production technologies are not accessible to people who are BVI. To address this issue, the TAGS set a priority to develop and discriminate a tool kit for engaging kids in tactile graphics at an early age (Strategy 52); towards this aim, the TAGS participants suggested launching a fundraising effort with a goal of $250,000 to deliver supplies to 1000 school aged blind children as a first step to reaching the 60,000 children in need of these supplies (Strategy 53). The TAGS community did not provide additional strategies for how to develop tools that empower people who are BVI to engage in tactile graphics design and creation. Members of the ASSETS community can focus on evaluating the accessibility of existing tactile graphics design and production systems, and they may subsequently design new systems based on how people who are BVI design through the sense of touch versus through existing visual content.

4) Design Considerations for Communication/ Representation of Content and Experience

4a. Tactile Graphics

The development of educational programming for tactile media design is in part contingent upon the broader community of tactile graphics consumers and producers addressing a series of issues identified by the TAGS participants. First, the TAGS data revealed that there is still disagreement within the tactile graphics design community about whether we are at a point when tactile graphics design standards are ready to be codified (GP4). By codification, the participants were referring to whether there should be a universal standard specifying which symbols and patterns to use within a graphic. The Braille Authority of North America (2010) provides the Guidelines and Standards for Tactile graphics, which were written for transcribers to use as they convert print and visual graphics into Braille and embossed graphics. The publication of these guidelines marked a significant advancement for tactile graphics designers, albeit they do not prescribe specific symbols or graphics to use and center on embossers as the production technology. Since the publication of these guidelines, scholars have made strides to rigorously develop and evaluate the accessibility of a consistent texture pallet across production technologies (Prescher, Bornschein, & Weber, 2017).

The TAGS participants argued for formal codification of symbols and a way to alleviate the problem that many tactile graphics are designed to be visually appealing rather than tactilely legible (GC7). Rosenblum (2018) similarly noted that designing from a visual orientation often results in clutter and detail that are not accessible through the sense of touch (Rosenblum et al., 2018). This concurs with what other researchers have found: whereas the tactile drawings are easy to recognize visually, average performance of BVI and blindfolded sighted individuals trying to read such drawings significantly drops (Heller, Calcaterra, Burson, & Tyler, 1996;

Lederman, Klatzky, Chataway, & Summers, 1990). This issue was raised by Aldrich (2008) when she proposed an agenda to orient mainstream researchers to the principal challenges in the field of tactile graphics and asked "Tactile graphics are usually simplifications of visual graphics. What would they be like if we designed them from scratch?"(Aldrich, 2008, p. 345). To address this issue, the TAGS participants suggested refining and distributing a set of guiding design questions to accessible content designers/ curators (Strategy 55). The TAGS participants did not suggest any explicit solutions for how to address this issue except the development of educational opportunities for sighted designers to learn how to design from the sense of touch (Strategy 19).

While the TAGS participants all recognized the importance of consistency of tactile graphics when a person is developing an understanding of symbolic representation, and needs to access information in time-sensitive situations—taking exams, navigating, following along with lectures, etc.—they also noted that they want "a diversity of materials just as any sighted person would want to look at different representations"(GC6). For example, a diversity of tactile designs is important when a child is first learning to tactilely explore their environment, and again when a person has developed a base level of tactile literacy and yearns for different styles of information representations. To the best of our knowledge, there have not been any studies that have explicitly investigated how consistency and diversity within the design of tactile materials affects a student's longitudinal tactile literacy learning progression.

Regardless of whether or not tactile graphic design should be codified, the TAGS participants noted that there is not a consistent protocol or method for evaluating how different design decisions and corresponding guidelines impact the learnability of graphics (GC9). A TAGS participant recommended that organizations like the NFB work with American Action

Fund to enlist people to test tactile graphics and help establish such a protocol (Strategy 45). In our estimation, such a protocol will need to consider a variety of variables, including: the tools being used to design the graphics, the production technologies, references to specific design strategies used, the order in which such strategies are employed, and the presence of audio or Braille descriptions of the graphics. In addition, it would be important to provide information about the evaluator's visual impairment, their prior experience and frequency of reading tactile graphics, whether they had previously seen representations of the subject matter being represented, the patterns in which they move their hands across the tactile graphics, and the duration they spend reading the graphics.

To the best of our knowledge, few studies have taken all of these factors into account when evaluating BVI people's comprehension of different tactile graphics and the effectiveness of different design strategies used in their creation. In one of the few recent studies, Nashleanas (2018) conducted a multistate survey on the perceptions of TVIs regarding the needs of students with visual impairments in high school mathematics courses to access and understand graphical information (Nashleanas, 2018). She reveals that visual experience may affect the level of accuracy with which students who are BVI perform graphing exercises, that BVI students access graphs in tactile form over sound or verbal descriptions, and instruction of BVI students entails more than solely providing SVI with tactile graphics or verbal descriptions.

Another TAGS identified factor that affects the fidelity of a tactile graphic centers on whether a tactile graphics producer pairs the design with the appropriate production technology (GP2). As we heard from the TAGS participants, if a design is intended to be produced using a thermoform machine but is printed on swell paper, the tactile experience will be entirely different. This issue was raised by Prescher et al. (2017), who argued for and evaluated tactile

patterns that can be used across production technologies (Prescher et al., 2017). Other scholars have recently looked at the learnability of concepts based on the application of different production techniques (Holloway, Marriott, & Butler, 2018; Kalia et al., 2014). However, there is a common inconsistency in the evaluation of the effectiveness of the production technologies (as well as the designs being presented) that makes it difficult to draw conclusions across studies.

Finally, the TAGS participants noted that many tactile graphics production technologies are not accessible (GP3). To this issue, the TAGS participants suggested establishing a working group to investigate accessible technology, create a list of accessible production technologies (Strategy 50), and distribute information (Strategy 51).To the best of our knowledge, the TactileView ("Tactileview," n.d.) offers some accessible features but is not comprehensive.

While many of these factors and issues are known anecdotally by practitioners engaged in tactile graphics design, there are still many opportunities for future research to investigate how and what graphical elements should be codified, how to approach the design and deployment of standards for consistency (beyond what has been suggested in the BANA guidelines), how to develop a consistent and robust protocol to evaluate the legibility of tactile graphics for a population with diverse abilities and levels of experience, and how to effectively address the accessibility of design and production technologies. For example, one possible research question regarding codification is whether design standards can be implemented around the world: can and should differences in semiotic systems be incorporated into a single code? Furthermore, while the TAGS participants focused on the codification of symbols and patterns, there is a great opportunity to examine how other visual conventions (e.g. visual layout, perspective, abstract/conceptual representations, etc.) can be conveyed through the sense of touch. Another important effort will be to evaluate all of the existing tactile graphics design applications to see if

they are accessible via a screen reader, as well as conduct empirical research with BVI designers to learn their prefered mode of designing and how to develop a program that responds to their interests and needs.

4b. Tactile Art and other Accessible Experiences of Art

The TAGS participants identified a different suite of design concerns that impact the accessibility of art rather than graphics. Whereas the design considerations for graphics centered on standards, methods of evaluation, the effectiveness of production technologies, and how people apply different production technologies to create their designs, in art consumption the primary issue focused on the provision of accessible labeling. The TAGS participants noted that there is a general dearth of Braille and audio labeling of art (AC7), to which the TAGS participants suggested providing audio, Braille, and large print labels in close proximity to the art pieces (Strategy 16). Additionally, the TAGS participants noted that it is important to provide Braille labels that can be read in an ergonomic position, e.g. horizontal (flat) or at a slight angle. For example, if attaching Braille labels to the wall, ensure that they are attached with a hinge so that people can lift the label to an appropriate angle and do not need to bend at the wrist to read the Braille (Strategy 17).

Additional issues included the layout of the exhibit spaces and presentation methods (AC6), which can be addressed if museum curators consider a person's physical orientation to the artwork; how does the artist intend the work to be viewed (Strategy 12)? It would be useful to consider the proximity of a piece of work to objects and the space needed for a person to move around a piece, to inform the development of navigational guides that suggest how a BVI person can physically orient themselves to artworks (Strategy 13), and to guide placement of tactile art pieces on pedestals (Strategy 14). Many of these strategies have been identified in the museum

studies literature (Argyropoulos & Kanari, 2015; Gallego & Núñez, 2014; Guarini, 2015; Manship & Hatzidimitriadou, 2015). We encourage the ASSETS community to draw on and adhere to and expand on these strategies in the design of accessible art displays and exhibits.

5) Access To - vs. Accessibility Of -

Unlike the other problems of practice, where the TAGS data revealed related issues, in this section, we discuss a problem of practice that we identify as Access "to" versus Accessibility "of". While it is common to use the terms access and accessibility interchangeably, we argue that there is an important distinction that needs to be made when using these terms in regards to tactile media.

Access is generally defined as the use of services relative to the actual need for care; lack of access occurs when there is a need for services but those services are not utilized. Barriers to access are those factors that contribute to preventing a person from utilizing a service when needed. For example, it is well established that there is a 'book famine' or 'knowledge famine'—the lack of access to fiction and non-fiction books, magaziness, newspapers etc. —which inhibits people who are blind and visually impaired from accessing text and graphical information materials as much and as freely as other people (Wise, 2014). The World Blind Union estimates that between one to seven percent of the world's published books ever make it into "accessible formats"—a broad definition which does not limit the format or the technique you use to make a book accessible ("The Treaty of Marrakesh Explained," n.d.). Less optimistic statistics suggest that, as of 2009, less than five percent of published works are available in accessible formats in the United States; 95 percent of books never become available to blind and partially sighted readers, who use alternative formats such as audio book Braille or large print (Pilch, n.d.).

Whereas the notion of access “to” tactile media and art more generally refers to the degree to which one may find, read, and reuse tactile media (greatly impacted by environmental factors), accessibility “of” the tactile media refers to the degree to which the content of the media itself can actually be understood by the consumer (factors pertaining to the characteristics of a piece of media or media experience). In other words, issues of accessibility “of” pertain to how the artifacts are designed and presented. **Table 4.11** summarizes the issues related to access to versus accessibility of, according to our four structural codes.

Table 4.11. Access To vs. Accessibility Of

	Access To	**Accessibility Of**
Art Consumption	Access to art consumption is affected by physical and social barriers that inhibit people from getting their hands on materials.	Accessibility of art is influenced by a person's prior exposure to art through touch and learned skills to interpret artistic content (but not related to the craft and design decisions made by the artist.)
Graphics Consumption	Access to tactile graphics for consumption is limited by supplies, avenues to finding materials, and instruction.	Design and productions decisions impact the accessibility of tactile graphics.
Art Production	Access to creating art is limited by pervasive societal beliefs, psychosocial experiences, and no exposure to materials and tools.	The accessibility of art creation and production experiences is affected by the inaccessibility of tools and exclusionary educational practices.
Graphics Production	Access to graphics production is dependent on the accessibility and cost of the design and production technologies.	The accessibility of tactile graphics production is dependent on the development/agreement about design standards and a person's exposure to this knowledge.

For example, we noted that the factors impacting access to art for consumption centered on the physical barriers and social barriers that prohibit a person from touching artworks. In many cases, this means that people who are BVI are prohibited from touching artistic materials (AC4, 5) or there are no materials available to be interpreted through the sense of touch (AC2). Lack of access may also be the result of museum policies(AC4), discriminatory attitudes (AC5),

or simply a person's lack of access to teaching and learning opportunities where touch is supported (AC9).

In contrast, the factors impacting the accessibility of art include the lack of effective Braille and audio labeling (AC7), and the dearth of intellectual resources to support a person's sense making of the materials they are feeling (AC10, AC11, AC12)— including how a person has been supported to use their sense of touch. The factors impacting access to tactile graphics for consumption centered on the fact that they could not get their hands on tactile graphics (GC1), due in great part to the lack of materials (GC2, GC5, GC10) or teaching and learning materials to support their tactile literacy. In contrast, accessibility of tactile graphics consumption centered on how the materials were designed and produced (GC6, GC7, GC8), as well as the use of multiple modalities in the delivery of the content (GC3).

Throughout our data, we noted that the factors impacting access to opportunities and resources to engage in art creation and production for people who are BVI has to do with limiting social beliefs (AP3) and lack of physical exposure to materials, tools, and instruction (AP1). In contrast, the accessibility of art creation and production rests on the accessibility of tools (AP7), inclusive education practices and learning environments, and teachers who foster a sense of belonging (AP5, AP3) and support tactile observation (AP4).

The factors impacting access to tactile graphics production activities centered on the fact that many tactile graphics design and production tools can not be used with screen readers (GP3) and the inhibiting cost of production (GP1). In contrast, the factors impacting the accessibility of tactile graphics sits in the lack of tactile graphic design resources and training programs (GP5), the lack of consensus around design standards (GP4), and the need for clear methods to evaluate tactile graphics (GC9).

We believe that this is an important distinction for the ASSETS community to make when approaching the design of systems to support BVI people's media consumption and production activities. Without access to something, it will not be accessible. If something is not accessible, it does not matter if they can get close to it.

The Interconnectedness of the Problems of Practice

Not only do each of the aforementioned problems of practice represent areas where practitioners and scholars can lead new investigations and enact new solutions, we must also look at all five of these issues as an ecosystem of problems of practice that are tightly connected to one another. For example, by taking steps to develop educational opportunities that celebrate touch as an important resource in a person's exploration of their environment (during both consumption and production), we are also challenging the pervasive attitude that touch is a deviant act.

Summary of Recommendations to the ASSETS Community

In **Table 4.12** we present a summary of the recommendations we have identified to support the design of socio-technical systems to support inclusion in art and tactile media consumption and production.

Table 4.12. Problems of Practice Summary and Recommendations to Support BVI Inclusion in art and tactile media and consumption

Problem of Practice	Recommendations to Access Computing community
1) Belonging and Conspicuousness	● Treat accessible exhibits and tactile media as boundary objects that provide an infrastructure through which diverse stakeholders can converge and collaborate, and spaces and cultures can transform. Consider whether the tactile-media focused technologies we develop

Table 4.12. Problems of Practice Summary and Recommendations to Support BVI Inclusion in art and tactile media and consumption	
	take into a ● Account the psychosocial aspects of the end-users' experiences and whether they entice a sense of belonging or perpetuate conspicuousness in media consumption and production.
2) Touch as Deviance	● Conduct empirical investigations with people who are BVI to better understand how they experience touch while consuming and producing art and graphics. ● Look to the tangible and embodied interaction community (TEI) and haptics design communities to assess whether existing tactile and haptic technologies have already been developed to create new touch-based interaction methods that also transform social attitudes about touch. ● Draw on the emergent body of literature from museum studies about t the need to overcome conceptual barriers about touch, and examine how to create spaces that set a different expectation for one's touch-based encounters with objects.
3) Inadequate Educational Programming	● Develop teaching and learning platforms and materials guided by the following requirements: 1) use of a defined and shared tactile vocabulary set, with examples of each concept in forms that are tactilely meaningful and can be linked to a range of visual metaphors or representational styles, 2) individualized learning paths responsive to a person's sociocultural, experiential, and visual perspectives, 3) prompts to support critical inquiry into a piece of artwork. AND develop a protocol to evaluate the effectiveness of such strategies. ● Engage in socio-technical research efforts to design, implement, evaluate, AND decimate inclusive art creation and production focused curriculum, creativity-support tools, etc. ● Create platforms where teachers could share their effective teaching strategies and learn about each state's' policy on how to identify blind children in order to enhance the distribution of resources
4) Nascency in Tactile Design and Representation	● Evaluate the accessibility of existing tactile graphics design and production systems, and subsequently design new systems based on how people who are BVI design through the sense of touch versus through existing visual content. ● Evaluate design standards implemented around the world and inquire into whether or not differences in semiotic systems can be incorporated into a single code. ● Examine how other visual conventions (visual layout, perspective,

Table 4.12. Problems of Practice Summary and Recommendations to Support BVI Inclusion in art and tactile media and consumption	
	abstract/conceptual representations, etc.) can be conveyed through the sense of touch. ● Draw on and adhere to these strategies in the design of accessible art displays and exhibits.
5) Access To vs. Accessibility Of	● Consider the distinction between Access To versus Accessibility of.. Without access to something, it will not be accessible to BVI individuals. If something is not accessible, it doesn't matter if they can get close to it.

Limitations

Here we address the limitations of our study, which pertain to the design and implementation of the TAGS, as well as the study design.

- **TAGS Design:** We designed the TAGS events to engage participants in a range of activities focused in tactile media, and through this, we sought to identify recurring issues and promote the TAGS participants' envisioned solutions. The strategies we used to design and implement the TAGS were intended to provide a range of BVI and sighted participants—coming from different professional backgrounds and experience levels—with direct hands-on experiences so that all participants could engage in conversations about the same materials. By designing the events in four segments (e.g., art and graphics consumption and production), we ensured that each of these topics was discussed. However, by implementing the TAGS in this way, we did not allow for the discussion to emerge naturally as they would have in more open-ended focus groups. It is possible that the ways in which the RPP conceived of these areas and the related activities introduced a confirmation bias. Furthermore, by bringing together such a diverse group of participants

we are able to get a wide view of the issues that affect the field. However, we were not able to differentiate the issues and strategies that are most relevant to each of the individual stakeholder groups, i.e. artists versus designer, people who are BVI vs sighted.

- **Recruitment and Sample Size:** The TAGS events were sponsored by the NFB, a blindness advocacy organization. While the RRP team reached out to the broader community to recruit participants, and we did not require participants to be members of the NFB, we acknowledge that this affiliation may have influenced people's interest in participating in the events. While 65 thought leaders who are concerned with tactile media consumption, production and instruction participated this study, we recognize that their perspectives may not represent all such practitioners.
- **Data Analysis:** While all of the RPP members consulted on the analysis of the data, I was the sole researcher engaged in the analysis of this data. We did not perform inter-rater reliability in the analysis of our data to demonstrate consistency among observational ratings provided by multiple coders.

Conclusion

In this paper we present a qualitative study focused on advancing the field of tactile media studies by providing an analysis of the factors and issues that impact how people who are BVI and invested stakeholders engage in tactile media art and graphics consumption and production. We identify problems of practice related to art and graphics that impede BVI people’s full inclusion in the media and information landscape: 1) Belonging and Conspicuousness; 2) Touch as Deviance; 3) Inadequate Educational Programming; 4) Nascency in Tactile Design and Representation; 5) Access To vs. Accessibility Of.

This paper extends the current work of the HCI and ASSETS community by 1) Providing a view of the experiences of people who are BVI and the issues they encounter when engaged in tactile media practices, which evidence larger problems of practice; 2) Proposing that tactile media (and their associated experiences) are boundary objects through which social exclusion is evidenced and can organized inclusive collaborations to ensure that people who are BVI have access tactile media experiences, and that those experiences are accessible; and 3) Proposing socio-technical solutions that address these problems of practice.

These findings contribute to both theory and practice. By identifying the issues that impact people's inclusion through tactile media consumption and production, we have a starting point to assess whether there are significant differences between different types of tactile media, their role in a person's life, and the factors—beyond the material—that affect how people are supported to engage in practices related to their consumption, production, and instruction. By understanding tactile media as a boundary object, we may start transform how teaching and learning environments and artifacts centered on inclusion in tactile media consumption and production will revolve around the creation on universal design as opposed to positioning people who are BVI as the sole benefactors of tactile experiences. By identifying and proposing socio-technical solutions that address these problems of practice, we open up new areas for research. For example, we plan to conduct further research to investigate many of the research opportunities identified in **Table 4.12.**

The research presented in this paper provides an important overview of the contemporary problems of practice that impact tactile media consumption, production, and instruction with tactile media, and ultimately inclusion of people who are BVI in the media and information landscape. Without such an overview of these problems of practices, a categorization of the

issues that evidence the problems, and the underlying experiences that create barriers to inclusion, people who are BVI will not be fully positioned to live the lives that they want. Furthermore, without inclusion of people in the media and information landscape, society at large will not be aware of all that touch has to offer and learn from the experiences of people who are BVI. There is a great opportunity for the ASSETS community to see tactile media as resources that build the fabric of an inclusive culture. By taking into account the problems of practice identified in this paper, we may innovate how we develop systems that position people who are BVI as agents of their media consumption and production experiences.

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Appendix: Welcome to the first NFB TAGS by Mark Riccobono

Good morning. I just handed Mike a piece of art. It is an elephant...This elephant was given to me by a member of the NFB of Maryland—Yasmin Reyazuddin, who is a determined young fighter for equality for blind people. So this art has some significance. That is one of the

[26]Designing Tactile Picture Books: Critical Making in Libraries to Broaden Participation in STEM Education and Careers

interesting things about art is that it depends on the perspective of the person and it depends on the circumstances in which you come to art.

I want to begin by reminding everybody, especially those that are not familiar with the National Federation of the Blind (NFB). NFB knows that blindness is not the characteristic that defines you or your future. We work every day to raise the expectations of the blind because we recognize that low expectations create obstacles between our people and our dreams. That we can live the lives we want and blindness is not what holds you back.

This gathering, to me, is really about raising expectations and using the power and diversity and influence of NFB to take art to the next level for blind people. This event is really on the leading edge of what we have been undertaking at the NFB for some time. We have been engaging in STEM education now for well over a decade and we have been incorporating art into those programs, almost since the beginning, and more recently we have been focusing a lot of energy on drawing, which is very interesting because many blind kids don't get the opportunity to draw at all. We think that drawing is one of the elements that is really important for encouraging blind people to be engineers.

This gathering is also significant in improving our understanding of the non-visual senses. Sometimes we only talk about the tactile, but during this gathering we hope to talk about all of the non visual aspects that don't have to do with simply seeing things, which people often default to, and I think, probably most people in this room know that of course sighted people miss a lot of stuff because they default to vision…There is a lot to do to improve the understanding of how non-visual aspects contribute to the understanding of how we perceive the world, and how all of us perceive the world—whether we can see or not.

Also, one of my hopes for this gathering is that we can continue to improve the practices for education—how we educate blind people about art, how to use art, how to play with art, how to express themselves through art, and hopefully set a foundation that we can use to pursue new avenues of providing non-visual information; But also, how we engage blind people in producing their own art and expressing scientific concepts through means that are not simply verbal or sound.

The work that we do at NFB is based on the hopes and dreams of blind people, and the authentic experience of blind people. I am really glad that we have a lot of blind people here to share in this discussion. I hope that we come out of this with some learning that will help us determine where we go next. What is the next big thing that we should do in this area to advance opportunities for blind people? A couple of things that I hope that are outcomes for us are: 1) that we can create some better understanding, some papers, some documents that we can use to continue to raise expectations in the education area for blind people; 2) we can get some ideas out of this gathering that will help us create new programming; we have been doing STEM programs now for over a decade, and we now call them STEAM.

If we put together a museum, which I think we need to do, we want to find ways to use art, not only to express the experience of blind people, but to convey to sighted people, not just what is is to be blind, but the social experience of being blind. We all know that with blindness comes a lot of negative societal attitudes...any blind person in this room has certainly experienced them. Could we create a museum that is authentic to us, use art to convey some of these difficult, cold, painful experiences that come from the low expectations that we encounter? I think that we could and that the discussion here can help inform us as to what we want to do with that.

I want to express my appreciation for Ann Cunningham, who I have known since 1999...I met Ann at her very first tactile art exhibit in Denver in 1999. I was a student at CCB…[and we have been] talking about art and have been slowly doing a couple of things—probably not quick enough for Ann, or really any of us. And we have done some great things together that maybe some of you have experienced. We invited Ann to our 2007 NFB Youth Slam and we got every student that came through—nearly 200—to make a piece of art, which we used to display here in the library until we tore it down to make room for the exhibit here today. That shows that we have been working on this for a while, but these two days are going to be transformation about where we are going next. Ann gets a lot of credit for that because she is persistent, imaginative, and most importantly, she doesn't want to be the only one that knows this stuff. She wants to make sure that we create a community of people who are engaged, contributing, participating, and know some of the techniques she is inventing, but also that you know techniques based on your own experiences. I think it is great that Ann is leading this effort with us these next few days. Finally, in closing, I hope that you take the time after these two days to personally give me your feedback about what we could do next, what the next big thing might be in this space, how we can do it better, and how we can transform the knowledge we have here into opportunities for blind people. Thank you for being here and enjoy the next few days and I look forward to the art that is going to be created. Mark Riccobono.

CHAPTER 5:

CONCLUSION AND FUTURE DIRECTION

The research presented in this dissertation was guided by the problem statement: There is a lack of empirically gathered and documented evidence about how people who are blind and visually impaired (BVI) and sighted effectively engage in tactile media consumption, production and instruction to support their own and other people's participation in education, civic life, and professional and personal endeavors. To add to the body of literature on media practices of people who are invested in creating full participation and inclusion in the media and information landscape—including both BVI and sighted individuals, I conducted three studies that were guided by four overarching research questions: 1) What considerations and/or practices do people who are blind and visually impaired engage in when consuming tactile media?; 2) What considerations and/or practices do sighted and BVI practitioners engage in when creating (making, designing, producing) tactile media?; 3) What considerations and/or practices do sighted and BVI practitioners engage in and develop when teaching with tactile media?; and 4) What design strategies can be implemented to address the factors that limit BVI people's tactile media consumption, creation, and instruction practices?

I engaged in a research through design (RtD) (Zimmerman, Forlizzi, & Evenson, 2007) as a means to answer these overarching questions. Engaging in a RtD effort enabled me—a design researcher who began this research without training in the field of vision science or education—to gain an understanding of the situation as it is through participant observation and collection of ethnographic data and through engaging in interventionist activities, i.e. the design of new tactile media (Chapter 2), the design and implementation of instruction focused on tactile

media design (Chapter 3), and the design and implementation of social learning experiences focused on tactile art and media consumption and production (Chapter 4).

In this conclusion chapter, I provide a summary of the findings from each study according to the first three overarching research questions, as well as a summary of the design strategies to address the factors that limit BVI people's tactile media consumption, creation, and instruction practices (Research Question 4). I subsequently identify the limitations of each study. Finally, I discuss three future research directions that have emerged from the work presented in this dissertation.

Summary

RQ1: What considerations and/or practices do people who are BVI engage in when consuming tactile media, and specifically, tactile graphics and art?

Study 1:

In Study 1, I found that parents and TVIs struggle to obtain tactile media for their BVI children. Specifically, some parents noted that there are limited resources for their children at their local libraries, and the materials that are available at the early intervention center "do not come home," meaning there are not enough resources for the center to loan them out to individual families. Second, I found that parents depend greatly on TVIs to help them learn about their children's specific learning needs. However, TVIs do not have time to provide individualized instruction about a child's tactile literacy abilities to parents. The deployment of the design probe revealed that despite the growing interest in 3D printing as a tactile media

production technology, it may not be the most appropriate method of production for tactile media to support emergent literacy learners.

Study 2:

In Study 2, I focused on understanding different community stakeholders' tactile media design practices, not consumption practices. While I did not collect any specific data about participants' tactile media consumption practices, I was successful in engaging the participants in a series of activities to activate their sense of touch and identify possible design requirements based on their own tactile explorations. One of these activities was a sudden blindness activity, during which I asked participants to feel tactile illustrations under sleep shades. I found that using sleep shades can be an effective tool to temporarily simulate the experience of blindness for sighted people.

Study 3:

During the Tactile Arts and Graphics Symposia (TAGS), I designed and implemented activities to engage people in consumption of various forms of tactile media. I learned about the different considerations that impact BVI people's tactile media consumption practices. I identified twelve issues that the TAGS participants expressed as impacting tactile art consumption, and ten issues that the TAGS participants expressed as impacting tactile graphics consumption.

RQ2: What considerations and/or practices do sighted and BVI practitioners engage in when creating (making, designing, producing) tactile media, and specifically, tactile graphics and art?

Study 1:

In Study 1, I found that many parents do not engage in the design of tactile media for their children due to a lack of time and resources. While TVIs have a strong understanding of young children's emergent literacy needs, they are too stretched for time to create such resources or educate parents about tactile reading specifically. The TVIs that I observed, who were highly interested or invested in creating tactile pictures, relied more on their own experience than the existing tactile graphics design guidelines (Braille Authority of North America, 2010; Edman & American Foundation for the Blind, 1992; Schuffelen, 2002; TAEVIS, 2002), or the guidelines for creating tactile pictures or illustrations (Claudet, 2014; Claudet & Richard, 2009; "Guide to Designing Tactile Illustrations for Children's Books," 2009). During my investigations into creating tactile illustrations (which resulted in the creation and deployment of a design probe), I found that the guidelines for tactile graphics are difficult to directly apply to the creation of illustrations or the creation of tactile media that are not embossed, raised line graphics.

Study 2:

In Study 2, I found that community stakeholders were interested in learning to design tactile pictures and graphics. But they did not know about the tactile media design guidelines. By charging the different stakeholder groups to create tactile pictures, I was able to observe how they approached the task differently. I found each group had a dominant focus in terms of design thinking. Also, I found that each group identified different design task requirements. All in all, I

showed that all the stakeholders identified key design considerations that are useful when designing tactile media.

Study 3:

In Study 3, I collected and analyzed data from three TAGS and revealed that there are a variety of issues that impact how people engage in tactile media production. By coding the transcripts from 84 participants, I identified eight issues/factors that the TAGS participants expressed as impacting tactile art consumption, and four issues/factors that the TAGS participants expressed as impacting tactile graphics consumption.

RQ3: What considerations and/or practices do sighted and BVI practitioners engage in and develop when teaching with tactile media, and specifically, tactile graphics and art?

Study 1 and Study 2 :

In Studies 1 and 2, I did not obtain significant results regarding the considerations involved with developing students' tactile literacy and the competencies necessary to become effective tactile media consumers and producers. While teaching and instruction was not the focus of Studies 1 and 2, in retrospect, I found the practices necessary to teach tactile literacy are very much connected to the knowledge and understanding one needs to have to create tactile media.

Study 3:

When I designed Study 3, I did not focus specifically on teaching as the central practices of my investigation. Yet, as I analyzed data, the need for more educational resources to support

practitioners' instruction with tactile media merged as a key problem of practice. Altogether, I identified 13 issues related to educational programming.

RQ4. What design strategies can be implemented to address the factors that limit BVI people's tactile media consumption, creation, and instruction practices?

Study 1:

In Study 1, by interacting with parents and TVIs of children with visual impairments, I identified several socio-technical design ideas. One such idea focuses on the design of a mobile application to support TVIs and parents to acquire tactile media and enhance communication between them about a child's tactile learning needs and milestones. I learned that TVIs and parents struggle to find or create tactile media, just as they struggle to find the time to discuss the young BVI readers' evolving interests, learning needs, tactile preferences, and developmental milestones. In turn, in Study 1, I proposed an application that would serve as a record keeper and communication aid between TVIs and parents. For example, the application would help parents and teachers find tactile learning materials from online 3D model repositories, i.e. Thingiverse, talking book libraries, and other keepers of tactile pictures and illustrations, and deliver these materials to the child's school. The application would provide age appropriate instructions for how to engage children who are BVI in tactile exploration of the materials during co-reading experiences, and provide live prompts to deepen the interaction. The application would capture the interaction via video so that parents, teachers, or other caregivers could share critical moments in the co-reading experience with one another and provide feedback about the child's development.

This application would greatly benefit from a 3D tactile picture digital library, with downloadable parts. In turn, the second idea I proposed in Study 1 centered on the development and population of a digital library of 3D printable parts and a community forum where for tactile picture readers and designers can share their experiences and help validate the materials generated by other designers. Finally, I envisioned embedding touch-receptive sensors and/or conductive paint onto the surface of the 3D printed models to obtain immediate feedback (finger touch spots) about what part of the images attract a child's attention.

Study 2:

One of the outcomes that emerged from Study 2 is that different stakeholders have different skill sets that contribute to the design 3D-printed tactile pictures. In turn, I envisioned the development of a design platform to support a multidisciplinary team to engage in the design of tactile media. I envisioned that the platform would support the formation of the teams, suggest design projects with actual clients, scaffold designers learning about the tactile graphics and pictures design guidelines, and suggest design strategies to meet the end users (teachers', parents', and BVI students' learning needs). The platform would support communication and collaboration between different team members by notifying participants of project activities, visualize progress and task allocation. I anticipate that a tool of this nature will require community management, and will look to the literature on social computing and creativity support tools to inform future designs.

Study 3:

In Study 3, I further identified the issues that impact the tactile media consumption and production experiences of people who are BVI (as experienced by the TAGS participants), as well as the TAGS participant's strategies to address these issues. I offered 15 recommendations

based on my analysis of the issues and strategies that the TAGS participants identified, and the formation of five core problems of practice (see **Table 4.2** for more details).

Limitations

Study 1:

There are several notable limitations to Study 1. One of the key limitations of this study emerged as a result of how I was prepared and positioned to capture data at the early intervention center. As a volunteer at the early intervention center (who was taking care of the young students) my ability to engage in rigorous observation of the TVIs and their direct engagement in creating tactile learning experiences for the children was limited. My role preclude me from being able to shadow the TVIs or parents through the course of their days and observe how they supported the students in consuming tactile media, or how they intentionally made or appropriated materials to create meaningful tactile learning experiences for their children.

In fact, in this study there was a clear lack of focus on BVI children's direct engagement with and consumption of tactile media. In order to understand young BVI children's tactile learning needs, one would need to observe their interaction with specific examples of tactile media—deployed with specific learning objectives in mind—in a consistent environment over a longer period of time. In addition, I would have needed to identify specific indicators related to emergent literacy practices, as well as take into account a other factors impacting their learning environments and abilities. I believe that there are efforts needed to understand how TVIs teach with and create tactile media for emergent literacy students. In turn, in future research, I would design a survey study with questions designed to gauge TVIs interest and availability to create

tactile pictures, availability to create materials, and how their schooling prepared them to create tactile media may have produced more informative results.

Study 2:

One key limitation of the study presented in Chapter 2 was the fact that I was trying to balance teaching the participants how to approach the design task, while teaching them to use new technology, and investigating their understanding of tactile media design. Furthermore, I did not provide the participants with a specific end-user to design for—a key consideration in many of the tactile media design guidelines. While this study provides insight into how novice designers approached the design task, it did not reflect the experiences of people with more experiences and those who are professionally responsible for creating tactile media (e.g., TVIs).

Study 3:

In Study 3, the territory I intended to cover during the TAGS was vast. There were many different forms of tactile media and intentions for their use. Future studies regarding the consumption of tactile media should be specific to a single type of tactile media (and corresponding production technology) and content area. To fully gain understanding of the examine a BVI person's tactile media consumption practices (and the conscious and subconscious considerations) one would need to first assess the subject's: age and visual impairment, disability and specific learning needs (often detailed in a student's Individualized Education Program), their comfort engaging in tactile exploration in public and private learning environments, their preferred exploratory procedures, whether they view touch as a deviant behavior and the impact of other psycho-social factors, their familiarity to the teaching/learning

content area and the use of visual symbolism in that area, their prior experience reading Braille and tactile media, their learning objectives, etc. Furthermore, the person making the assessment of a person's engagement in tactile media consumption practices, it is necessary for that person to have an expertise in the subject matter, provide auditory and Braille labels and contextual information.

Similarly, while this study provided an overview of the issues that impact people's tactile media creation and production practices, it did not provide deep insight into the how to address such issues or how tactile media designers can improved their design practices—beyond suggestions like assessing the accessibility of tactile media design and production technologies to increase inclusion.

Future Directions

Two underlying social phenomena became grossly apparent while conducting the three investigations presented in this dissertation. First, many people who are BVI are excluded from participating in the creation of media, despite: A) clear evidence that people who are BVI are interested in and able to make contributions to interpreting, consuming and creating various forms of media, and B) the growing awareness of the inequity that exists within the media and information landscape (Goggin, 2017). Second, there are few training opportunities for teachers of the visually impaired, technology developers, and other invested stakeholders who want to learn how to create effective tactile media for people who are BVI. The task of creating accessible media and information demands engagement with an interrelated set of considerations—different modes in communication and learning, semiotic choices, sociocultural values and influences, and sociotechnical opportunities and constraints—as well as critical

reflection about the accessibility of our existing media and information systems and how people are positioned to participate in consumption, creation, and prosumption.

In the future, I aim to conduct research focused on 1) Increasing the inclusion of BVI people in the creation of media, 2) Developing educational resources to engage more TVIs, mainstream teachers, students, instructors, and technology developers—blind and sighted, novice to expert—in tactile media creation, and 3) [more generally] strengthening tactile media studies as an interdisciplinary field of research.

Increasing the Inclusion of BVI People in the Creation of Media

Through designing and implementing this research I developed a new understanding that creation, design, and production are important practices in the development of every persons' multimodal and media and information literacies. In fact, creation, design, and production are practices that are agentive in nature and support self-determination (Sheldon, 1995). Creative acts also people in critical reflection about their own and other people's agency within social, technical, and environmental systems (Drucker, 2017). As evidenced in this dissertation, there is a great need for further action to address the exclusion of people who are BVI as creators, designers, and producers of media.

In turn, one of my future research goals centers on addressing the socio-technical gap between what we know we must support socially—inclusion of people who are BVI in media creation—and what is currently supported technically—accessible ICT and access technologies that make media creation. This gap is particularly relevant at a time when creation has become a valued practice in STEAM and Making education.

In order to address this gap, I have already started conducting research to assess the accessibility of existing access technologies, creativity support technologies, and Do-It-Yourself and Maker Technologies. For example, in collaboration with Ryo Suzuki, I developed and evaluated a low cost, electromagnetic tactile drawing aid enables people who are BVI to follow an automated tracing guide (Suzuki, Stangl, Gross, & Yeh, 2017). Additionally, I have assessed how the Paper Mechatronic system—developed by Dr. Hyunjoo Oh—can be used to enable people who are BVI in the design of paper crafts that move dynamically through a microcontroller.

In the future, I will continue to conduct human-centered design research to guide the development of technologies that support inclusive media creation and, more broadly, address the social attitudes that have led to the sociotechnical gap. I will continue to build coalitions between my colleagues in computer science, vision science, education, and art, media, and design studies to create new accessible media creation tools and technologies. For example, I have plans to extend the FluxMaker project (Suzuki et al., 2017) and investigate how to develop interactive systems that kinetically train people who are BVI to learn about the representation of visual metaphors and visual conventions.

The design and development of the aforementioned tool raises important questions about the relationship between people with disabilities, technical systems, and the power dynamics in which they are created. In turn, while conducting this research I will investigate:

- In which ways are people with [X] disability interested/ engaged in developing access technologies and access media for themselves, and or their peers with disabilities, and why?

- In which ways are people with [X] disability interested/ engaged in participating in projects led by people who they do not identify as having the same life experiences, and why?
- How does a person's interdependence with technology affect their sense of agency in the creation process?

Based on these investigations, I will develop a framework that exposes the ways in which access technologies intermediate the media creation practices of people with disabilities. I will use this framework to formally assess a variety of creativity support, Maker, and DIY technologies, and develop new accessible creation tools. I believe that my future research in this area will contribute to the fields of Human-Computer Interaction (namely, the Tangible and Embodied Interaction, Design of Interactive Systems (DIS), Accessibility in Computing (ASSETS), and Computer Shared Cooperative Work (CSCW) communities).

Development of a Pedagogy for Inclusive Tactile Media Creation

As evidenced in the studies presented in this dissertation, the task of creating accessible media and information demands engagement with an interrelated set of considerations—different modes in communication and learning, semiotic choices, sociocultural values and influences, and sociotechnical opportunities and constraints—as well as critical reflection about the accessibility of our existing media and information systems and how people are positioned to participate in consumption, creation, and prosumption.

Accordingly, I also aim to develop a Pedagogy for Tactile Media Creation that can be used to broaden participation in tactile media design, and become a resource for teaching students, instructors, and technology developers—blind and sighted, novice to expert—to become

tactile media designers. The pedagogy will center on developing students understanding of the sensory modes that people use to engage in tactile communication and thus tactile media culture; tactile, audio, and visual. In its current form, each of these sensory modalities forms a central teaching and learning area. There are a set of core instructional goals associated with each teaching area, categorized under four headings: Medium/Mode Considerations, Semiotic Considerations, Socio-Cultural Considerations, and Socio-Technical Considerations.

My aim for this pedagogy is that it will help addresses the lack of instructional materials focused on tactile media design, as well as the need for educational experiences that engaging students in critical reflection about accessibility, access, and other issues that affect equity and inclusion in the media and information landscape. Through designing and implementing this pedagogy in formal and informal settings, I aim to investigate the following questions:

- How does learning to create accessible media cultivate students' technical abilities, critical perspectives about access and equity, and overall media and information literacy?
- How does direct engagement in media creation impacts BVI people's technical abilities, perspectives on access, sense of self-determination, and media and information literacies?

In a separate direction, I plan on conducting tactile media design ethnographies focused on how people engage in tactile media creation around the world. To date, there is little formalized scholarship on such practices. Furthermore, this effort will contribute to a heated discussion amongst tactile media designers and producers: Should tactile media design conventions be standardized, or is it too early to make a universal collection of tactile representations? I will draw on this work to develop an online teaching and learning community, where people can share their work, provide each other feedback, and directly involve others in validating the fidelity of their work.

Developing a Tactile Media Studies Community of Practice

As presented in this dissertation, research on tactile media attracts scholars and practitioners from a variety of fields. However, the body of literature on the subject is incredibly scarce and there is still no effort to create a coherent research agenda that translates work on tactile media from perceptual and cognitive psychologists, literacy scholars, special education scholars, mechanical engineers, HCI researchers, media and communications scholars, and art historians. Accordingly, another strand of my research focuses on developing the field of Tactile MediaStudies.

While the TAG Symposia laid the groundwork for the creation of a Community of Practice (Wenger, 1998) of scholars and practitioners investigating the perceptual, cognitive, social, and technical factors related to tactile media consumption, creation/design, production, and instruction, there is still work to be done. As a first step I aim to cultivate a Tactile Media Alliance and develop a Tactile Media Community Atlas that connects practitioners and scholars invested in tactile media consumption, creation, and instruction from all over the world. The Atlas will function as a boundary object to gather the academics and practitioners around a core set of research questions dictated by the problems of practice identified in Study 3.

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