SynthAccess: First Steps Towards Improving Synthesizer Accessibility for Blind Musicians

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Abstract

The SynthAccess project improves the usability of analog synthesizers in learning and performance for blind and low vision users. Many analog synthesizers could be made accessible because their controls can be physically operated without requiring digital screen navigation. However, a consistent lack of access considerations across these devices makes analog synthesizers especially difficult for blind and low vision learners. In this work, we focus on the layout and signage of a synthesizer lab, adaptations to existing devices such as braille labels, patch diagram overlays, 3D-printed knobs, speech synthesizer software, and resources to allow others to adapt additional equipment. Through an iterative co-design process with a blind music technologist (who co-authored this article), we share resources for adapting synths along with design considerations to promote analog synthesizer accessibility more widely.

Keywords

Synthesizers, Accessibility, Co-design, Blindness

1 Introduction

An expository chronology of the efforts made in the history of accessibility for blind and low vision (BLV) musicians would be incomplete without a mention of “The Original New Timbral Orchestra” or “TONTO,” a massive analog synthesizer built in the late 1960’s by Malcom Cecil and Bob Margouleff. TONTO was most famously used by Stevie Wonder on many hits, including “Superstition” and “Living for the City.” It is worth mentioning that, while Wonder is credited with “…control[ing] the final arrangement” of these tracks via the instrument, “…Cecil and Margouleff were in perpetual motion [behind Wonder], patching together sounds in real-time like musical switchboard operators” [27]. This historical trend of sighted assistants’ required presence in facilitating a BLV musician’s realization of their work has been the norm, perpetuating the idea that such machines are too abstruse to be understood without sight.

Few synthesizer designers and manufacturers have made a concerted effort to address these accessibility challenges. One notable exception was in the development of the ARP 2600 synthesizer in 1971. Wonder advised its eponymous creator, Alan R. Pearlman, to use slide potentiometers, with a vertical orientation designated for scaling input signals and a horizontal orientation for offsetting input signals. This design language offered a major advantage over Robert Moog’s design preference of rotary potentiometers and unmarked knobs, which did not inherently offer any tactile indications as to their respective parameter’s functions. Wonder demonstrated his ARP 2600 on national television, and is known to have commissioned a custom braille overlay [10, 15].

Based on available standards and resources, accessibility provisions for music software appear to be better implemented for software than hardware. Music software can leverage an ecosystem of Access Technologies (AT) and digital accessibility standards, such as WCAG (Web Content Accessibility Guidelines) [36]. Contemporary music software applications, including Digital Audio Workstations (DAWs), control panels for audio interfaces, and plug-ins for synthesis and effects processing use Graphic User Interfaces (GUIs). BLV musicians can use AT to navigate and operate these GUIs: for example, digital magnifiers and color contrast settings alter an interface’s appearance to support users with some working vision, while screen readers speak the contents of the screen, such as the state of a switch and the value of a slider [1]. However, GUIs must be programmed to work properly with AT. Until 2021, JUCE, the GUI framework behind Ableton and other music software, lacked AT support entirely [13]. Even when an interface is technically accessible, it may not be usable or fun. Fundamentally, GUIs are designed to be used via pointer (mouse or touch) and visual feedback, not keyboard and text-to-speech. They can be tedious to navigate and cognitively demanding to learn nonvisually [30]. Open-source initiatives, like Flo Tools [6] and Surge [34], innovate in accessibility, but such initiatives rely on volunteer labor to maintain.

This complicated landscape of software accessibility motivates the need for music hardware solutions. Hardware avoids the aforementioned accessibility challenges, and its physicality

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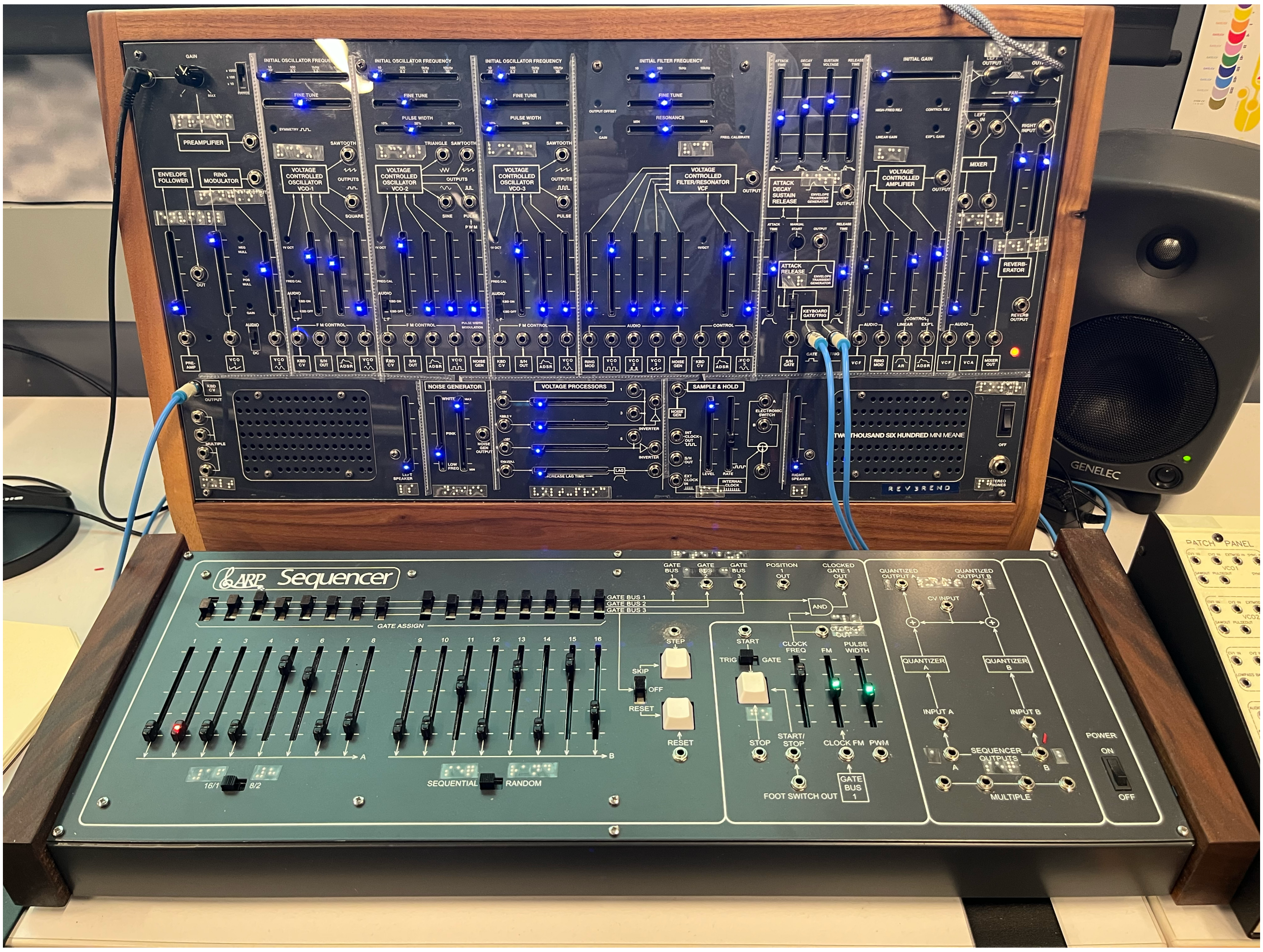

Figure 1: TTSH (Open Source ARP 2600) modified with clear acrylic overlay and braille labels.

enables performers to build spatial memories of layouts and performance gestures. As one develops expertise with a particular synth or modular setup, the need to see it diminishes. However, commercially-available devices are, in most cases, not accessible out of the box. Synthesizers in which significant I/O happens via screen are the least accessible because blind users can neither access the screen nor connect their AT, as they might do with mobile/desktop software. Even devices with no screens are inaccessible without accommodation. Modular synthesizers feature small printed text along with buttons and knobs that use visual cues to convey their state. Indicating awareness of this gap, in 2014 Moog released "Braille edition" of their Sub Phatty synthesizer "inspired by Stevie Wonder" [9]. However, this design is no longer available, and braille overlays were not manufactured for other synthesizers. Important, but often overlooked, accompanying materials are also inaccessible: the text in manuals may be accessed via screen reader or Optical Character Recognition (OCR), but visual figures are rarely described, forcing BLV users to learn without patch diagrams.

There is certainly interest among BLV individuals and music communities to learn and use analog synthesizers. Since 2017, The Texas School for the Blind has offered an evening class called "Synthesis and Sound Design" in which residential students learn to operate several synths and a small recording studio [5]. Furthermore, the lead designer of CHOMPI, a tape music instrument, speaks openly about how his severe vision impairment led him to create "a more tactile experience based on listening rather than menu diving on a small screen" [11]. Finally, there are many online forum posts by users who report vision loss and seek guidance on accessible synthesizers. Community suggestions include device features like real estate to adhere braille labels, consistent layouts, and no menu diving, e.g. [35].

This paper describes ongoing work to design and establish standardized resources to improve the accessibility of synthesizers for BLV users. The primary contributions are as follows:

- We share open-source resources for adapting synthesizers in our lab, including historical synthesizers such as the ARP 2600, contemporary commercial synthesizers such as the Moog Mavis and Sequential Prophet 6, and independent DIY synthesizers such as the TTSH (Figure 1) and Deckard's Dream. These resources include style guides, specifications, and examples for braille labels, tactile booklets, integration of speech synthesizers, and other accessible materials (Table 1). These works are distributed in an open source repository to encourage manufacturers and enthusiasts to create materials for other synthesizers.
- We demonstrate preliminary accessibility of these resources through an ongoing, iterative co-design process involving a blind musician and co-author.

Category	Intervention	Description
Adaptation	Overlay	Laser cut overlay placed on top of synth, customized with braille labels. Aka. "spit guards."
	Tactile Knob	3D-printed knob caps with tactile position indicator
	Text-To-Speech	Computer program that plugs into synth and speaks the name/value of knobs. Also can read screen contents.
Reference	Tactile Booklet	Raised line reference booklets created with swellform machine. Uses tactile graphics and braille to describe synthesizer components.
	Style Guide	Set of braille shorthands and iconography to promote consistency across overlays and reference booklets.
Laboratory Policies	Reachability	Clips and holders for keeping cables within reach of devices.
	Navigation	Grip tape and fixed chair locations.

Table 1: SynthAccess Interventions

- We suggest directions for future research to broaden the development of further accessibility tools.

2 Related Work

Our work builds on prior research in music technology accessibility for BLV people and co-design methods for NIME.

2.1 Technology for Blind and Low-Vision Musicians

In recent years, a surge of research projects have addressed access barriers in music technology for BLV people [37]. Formative studies with music educators/learners [3, 16], BLV performers/composers [24, 26], and BLV audio producers [30, 31] have identified consistent challenges including a lack of targeted teaching resources, inaccessible music notation, and complicated technology workflows. Scholars have explored design interventions across modalities leveraging haptics, e.g. to improve navigation within DAWs [14, 33] and communication during lessons [17], AR/VR to enlarge and navigate sheet music [2], and electronic music learning settings designed to integrate AT [25]. A 2025 systematic review notes four trends in design goals across literature addressing music technology accessibility for BLV people–(1) spatial awareness, (2) access to information, (3) (non-verbal) communication, and (4) memory–and identifies two gaps: "collaborative music technology and inclusive real-world testing" [37]. SynthAccess addresses both gaps: First, we use an interdependence framing of design [4] leading us to consider interventions beyond adapting individual devices, such as lab policies to promote inclusive behaviors of all users. Second, our design process is rooted in continuous testing and iteration with a blind music technologist.

2.2 Collaborative and Participatory Design in Accessible Music Interaction

Co-creation of musical interfaces–ie. between developers, composers, performers, choreographers, etc.–is fundamental to NIME. As NIME researchers have increasingly considered design impacts to learning and accessibility (e.g. [18, 23]), co-design with Disabled musicians and learners has been employed formally as a methodology. For example, Danneman demonstrated the use of jam sessions as participatory design studies [7]. In sessions with five children with disabilities, researchers gathered physical capabilities and musical preference organically through collaborative musical play, translated their findings into performer profiles, and finally prototyped musical instruments. Additionally, May et al. led a workshop with 27 Deaf and Hard-of-Hearing children resulting in unique design considerations for haptic art instruments [19]. Our project responds to Skuse and Knotts' call to "listen to the needs and concerns of disabled musicians around the making of music, hardware and software platforms" [32]. A blind collaborator is a core member of the design team. The present study kicks off a long-term effort promote synthesizer access sustainably.

3 Methods

Madeline (Maddy), Stefanie, and R. Luke met weekly on Monday mornings and Tuesday evenings in the NYU Audio Lab from September to December 2025, while other members of the team worked asynchronously to produce the interventions described below and joined meetings ad hoc. In this section, we describe the context behind this project, the initial meeting that sparked research, and the accessible design efforts that followed.

3.1 Study Context and Background

This effort to develop accessible analog synthesizer adaptations is motivated by our collaborator Maddy, and our goal to make the NYU Audio Lab inclusive of students and community members. Maddy is a classically trained musician who sings and plays piano and violin. Blind from birth, she is fluent in braille and braille music. While Maddy has experience using DAWs (CakeWalk Sonar and Logic) and live coding using Tidal Cycles [20], Maddy is relatively new to analog synthesis. To supplement her other undergraduate courses in Music Technology, some of which have frankly not provided adequate accommodations, Maddy enrolled in an independent study with Luke to learn concepts in synthesis through using analog synthesizers.

The NYU Audio Lab is a shared space designed to promote exploration, learning, and research rather than to mimic a commercial recording studio. It features a collection of modular synthesizers along one wall and non-modular synthesizers at a center table. Some synths are custom-built, such as the TTSH open-source reimagining of the 1971 ARP 2600, (described below), while others originate from the 70's and 80's, such as the 1975 Roland System 100. The space also features a multi-channel audio system and auxillary equipment, including mixers, audio interfaces, and MIDI keyboards, to support working with the synths.

3.2 September 2025 Brainstorming

In September, 2025, prior to Maddy's Independent Study, we gathered to brainstorm interventions to help Maddy to independently work within the lab. At this stage, we had designed 3D-printed braille overlays in collaboration with Mountain Lakes Library Makerspace as a proof-of-concept, but had yet to think at scale how Maddy's learning may be supported. We discussed interventions related to content and identified the need for tactile documentation that could accompany the synthesizers. We considered other interventions, including modifications to individual instruments, and quickly implemented a set of lab policies (described below). We also wanted to respect the value of objects in the space. For example, we considered adhering braille labels to all equipment, but we worried that removing labels, e.g. for making improvements, could damage expensive equipment. Thus, we also decided to continue producing overlays with a laser cutter and clear acrylic to expose signifiers already on the devices and streamline design compared to 3D printing. While we experimented with hardened nail polish to create raised lines, we used a braille label maker to add braille and raised lines to delineate modules.

3.3 Iterative Design of TTSH Tactile Reference Booklet

We chose a DIY clone of the classic ARP 2600 called the "TTSH" (Two Thousand Six Hundred) by "The Human Comparator" as the first synthesizer to receive these experimental adaptations. It was selected for its intuitive interface, which features differentiable sliders, and its self-contained semi-modular format was designed to teach the fundamentals of synthesis. Its relatively large front panel surface area (25" x 16" x 8") led us to believe we could replace all printed text with braille, but there was not enough space: Standard guidelines, which ensure that braille is legible [22], prevented us from resizing or rotating braille to fit labels on the device. Thus, we chose to design an accompanying tactile reference booklet that could include and define all components of the synth.

We iteratively designed three tactile reference booklet prototypes with Maddy. (Figures 2 and 3 show the first two.) To create tactile graphics, we use a Swell Form machine, a device that heats up black ink printed on swell paper, causing it to puff up and rise off the page. Other colors do not swell, meaning carefully designed pages can support both visual and tactile access. For example, the purple text we use is legible in print, but will not be felt by a blind reader. For version 1 (Figure **??**), we were inspired by the signal flow lines drawn on the TTSH. We based our initial design on work by Race et al. who iteratively made tactile circuit diagrams, providing guidelines on line thickness, spacing, layout, iconography, texture, and swell braille font size [28, 29]. In translating these guidelines from circuits to synthesizer resources, we faced two challenges. First, it was impossible to fit an entire synthesizer on one page, so we split it into modules and designed a map to indicate which module that page referred to, shown in the bottom right of Figure 2. Second, we realized that tactile graphics make it difficult to distinguish between printed content, such as signal flow diagrams, and physical controls. While additional textures could help separate signifiers from physical affordances, they would also increase reading complexity.[1] Thus, we created a second representation of the surface, shown in the bottom left corner of Figure 2, that only conveys the physical affordances of the TTSH without any labels. In reacting to this version, Maddy felt the signal flow was not useful and just needed reference materials to know exactly what she was touching. Additionally, the density of the smaller representation increased efficiency in identifying controls.

For version 2 of the TTSH tactile reference booklet, we removed the signal flow graphics and worked towards improving legibility. Shown in Figure 3, we matched the layout of the TTSH region, but included only controls and labels. Because there was limited space to fit braille adjacent to each control, we used dotted lines (with smaller dots than braille cells) to associate controls with labels. The reference map remained in the lower left. We showed this prototype to another blind adult, who is experienced creating tactile graphics. While they expressed that it was readable, Maddy found it to be cluttered and that the connection lines were difficult to follow. Given that braille readers glide their fingers from left to right, Maddy advocated for keeping groups of labels aligned as much as possible. In version 3, the current version (Figure 5), we removed the connector lines and moved the map up expand room for other content. To align the braille horizontally, we created abbreviations of common labels and increased the size of icons by 30%. We codified our findings into a style guide and used it to complete the booklet for every region of the TTSH.

3.4 Ongoing Explorations Beyond TTSH

Following the completion of the TTHS tactile reference booklet, we created a style guide and set of shorthands and icons from the TTSH (detailed below). We used it to adapt additional synthesizers from the lab, attempting to maintain consistency across devices while introducing new symbols and shorthands when necessary. We also created a set of resources for the Moog Mavis, selected due to its affordability, portability, and potential for future workshops. Because the Mavis uses knobs instead of sliders, with only white lines to signify their orientation, we designed 3D-printed caps with tactile indicators (Figure 4). Additionally, we programmed synthesized speech software to offer an alternative way of determining names and values of affordances and to ensure that devices with screens and hidden menus could be accessed.

Design explorations are ongoing. In particular, we continue to experiment with workflows to apply braille and other raised signifiers to laser-cut overlays. We have explored both DIY (Swell Form) and industrial (UV) approaches. First, we created tactile preset cards that sit atop the Moog Mavis, based on the printed "preset" cards that are bundled with Moog semi-modular synths (Figure 4). However, the workflow is tedious in practice. Each card must be printed using a standard printer (with preset indicators added digitally or via black marker), then passed through a Swell Form machine, and finally laser cut, requiring careful alignment. Swell paper can not be heated after it has been cut, because it gets caught in the gears causing a fire hazard (We discovered the hard way.) Additionally, the cards themselves were not successful - the tight spacing of the patch bay meant that raised lines were not perceptible in close proximity to the ports. Second, we experimented with a Mutoh Xpert Jet UV printer, housed in a nearby university lab, to automatically apply braille labels and textures to overlays. While this could replace the process of manually applying braille labels, we have not yet successfully aligned the

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[1] We use "affordances" and "signifiers" following Norman's definition [21]. Affordances are material properties that allow for an action, while signifiers are (usually visual) cues that signal the presence of affordances and information their behaviors. A challenge in designing tactile graphics and overlays is that touch replaces sight as the sense involved in processing signifiers.

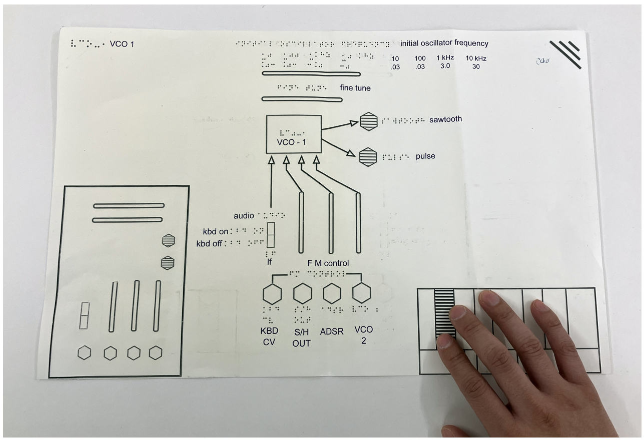

Figure 2: Prototype 1 tactile reference page for the VCO-1 module of the TTSH.

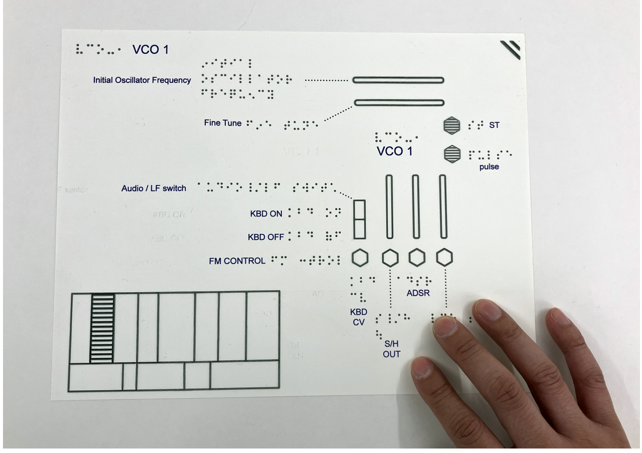

Figure 3: Prototype 2 tactile reference page for the VCO-1 module of the TTSH synth.

print on top of the laser cut. Both explorations show the difficulty combining multiple digital fabrication tools to produce one artifact in a DIY setting.

4 Components of SynthAccess

The SynthAccess project consists of three main categories of interventions: 1) synthesizer adaptations/additions, 2) accompanying reference documentation, and 3) space considerations (Table 1). In this section, we outline the purpose and implementation of each approach, and, when relevant, note design tensions. We then report Maddy's preliminary experiences. All interventions, including image/CAD files, source code, and policies, are open-source.[2]

4.1 Synthesizer Adaptations

Synthesizer adapations include tactile overlays with braille (similar to the Moog Braille Phatty [9] and Wonder's ARP 2600), 3D-printed knob caps, and speech synthesis software for announcing control titles and values.

4.1.1 Tactile Overlays. We installed transparent acrylic overlays with braille labels for nine diverse synthesizers in our collection: the TTSH and original 1971 ARP 2600, the 1975 Roland 100 Series and SJ-101, the Sequential Prophet 6, the Black Corporation Deckard's Dream and ISE-NIN, the Oberheim SEM, and the Moog Mavis. The fabrication process involves measuring panel dimensions and component spacing (sliders, knobs, and mounting points) then creating SVG layouts in Adobe Illustrator. After laser cutting cardboard to confirm alignment, we laser cut the final overlay from transparent acrylic and mount it onto the synth panel. We then attach braille labels, made using a low-cost label maker, to the acrylic surface to identify key sections of the modules and patch points (Figure 1).

4.1.2 3D-Printed knob caps. The Moog Mavis features a small form factor with miniature knobs that use thin white lines to signify orientation. Thus, a blind user cannot tell a knob's position without turning it to one extreme and then reorienting. Because the knobs are difficult to remove, we created caps that fit snugly on top with physical indicators. After a few revisions in which we experimented with filaments and diameters, we arrived at the current version shown in Figure 4. Over time the caps can become offset from the knob's actual position and must be corrected.

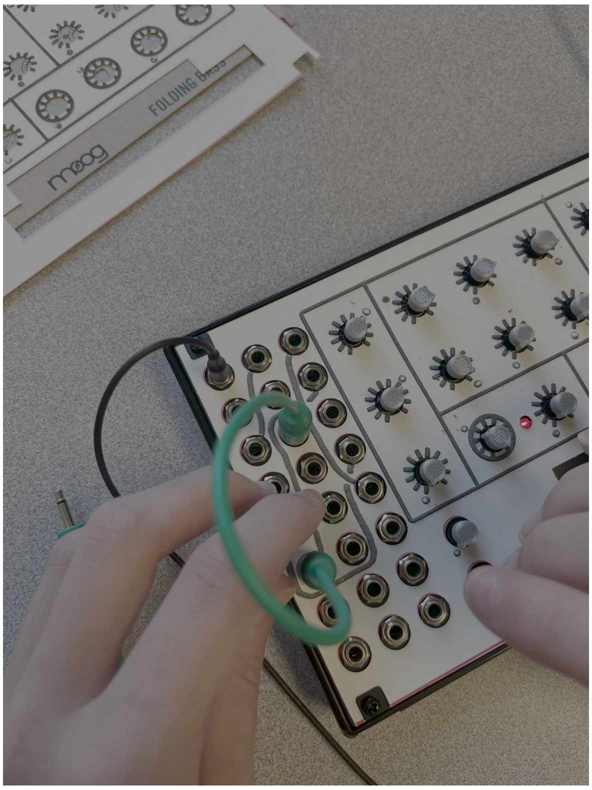

Figure 4: Moog Mavis modified with tactile preset card overlay and 3D-printed knob caps. Raised lines showing where to place patch cables are difficult to feel and follow between the jacks.

4.1.3 Speech Synthesis. We designed a speech synthesis software that reads aloud the affordances on synthesizers as they are touched (shown in use in Figure 7). Our software currently supports any synthesizer that transmits affordances over MIDI and can transmit in reverse so that key commands on the user's

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[2] SynthAccess Repository: https://github.com/IDMNYU/synthaccess

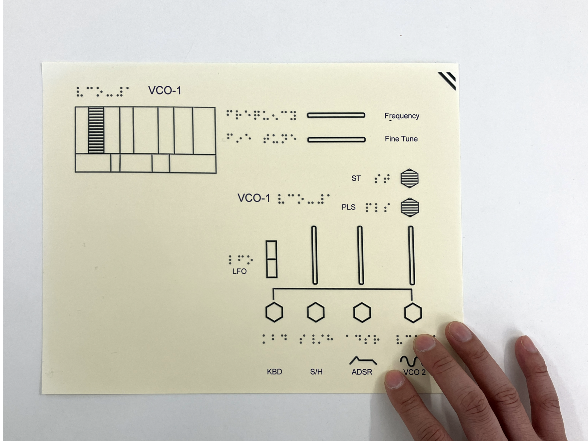

Figure 5: Working version of the TTSH tactile resource booklet - VCO-1 page shown.

computer can be mapped to digital controls that would require sighted interaction (e.g. "menu-diving").

Our software is implemented as a Max patch using Maxess, a collection of Max/MSP externals that integrate with AT, and allow us to use built-in computer speech synthesis [8]. Each hardware synthesizer is represented with a JSON file using a format we standardized for others to follow. Broadly, each file is a list of definitions for how to interpret MIDI program change, continuous controller (CC), non-registered parameter number (NRPN) messages, and key press events. Synthesizer manuals usually list CC and NRPN values, as they afford users alternative control methods.

We have written JSON files for three synthesizers: the Sequential Prophet 6 and the Deckard's Dream and ISE-NIN, both from Black Corporation. We then collaborated with the Focusrite group (which includes Sequential, Oberheim, and Novation as subsidiaries) develop JSON files for their contemporary product line. When plugged into a synthesizer's MIDI out port, our software produces the name and, if configured, the value of controls as they are touched by a user. A benefit of this approach, beyond other interventions, is that it can convey information only accessible via LED or screen. For example, on the Sequential Prophet 6, when a user presses the "high pass velocity" button, the only feedback produced is a light toggled. Using our software, a plugged-in laptop will state, "high pass velocity on" or "high pass velocity off." Our software is also capable of decoding multi-affordance systems that normally output to a 7-segment LED array or other visual system, such as the three-digit program / bank combinations on the Prophet 6 which are transmitted via a combination of MIDI commands.

4.2 Tactile Documentation

To date, we have implemented tactile reference booklets for the TTSH ARP 2600 (Figure 5), Roland 100 series and the Moog Mavis following style guidelines determined through the third TTSH revision. The booklets are made entirely using black and purple ink on swell paper, heated up to produce raised lines with a Swell Form machine.

Booklets are structured such that modules early in the signal flow (i.e. preamp, VCO, etc) are in the beginning pages, whereas modules later in the signal flow (like effects) are near the end. This structure serves as a surrogate curriculum, allowing Maddy to explore the synthesizer using the beginning pages, and gradually advance as her patches become more complex. She has also developed a workflow for quickly referencing the booklet while patching, where she reads the graphics with one hand and feels the synthesizer with the other. This reduces the need for her to memorize controls and how they connect.

4.2.1 Style Guidelines. To inform consistency across tactile reference booklets, we designed a style guide consisting of a common set of symbols, vocabulary, and layout considerations. The symbols include both the physical affordances of the synthesizers (switches, sliders, and printed graphic symbols) and common icons that are used across synthesizers, such as sine waves and ADSR diagrams. The size and line thickness of these symbols is informed by Race et al's research on circuit diagrams [28]. Because our process began with the TTSH, we often debate when we need to introduce new symbols. For example, the Roland 100 series uses a distinct large round power button. While we could have used an identical switch icon as the TTSH, ultimately, we decided to use a new symbol.

Because of space limitations on the front panels of the synthesizers, we cannot label the full names of the regions. Instead we use a braille shorthand for the labels, when possible using common abbreviations known by electronic musicians. For example, VCO is a typical abbreviation for the region named Voltage Controlled Oscillator. In the tactile booklets, we use both the unabbreviated names and abbreviated shorthand for reference.

Finally, our style guide includes recommendations for organizing the entire booklet. Every booklet begins with a key that defines all symbols specific to that synthesizer. Each page of the booklet refers to an individual region and includes an orientation map in the top left corner. Elements of the designs are kept no less than one-eighth inch apart to reduce clutter and promote tactile legibility. Braille is printed using black ink and a Swell Braille font while print text is written in purple to ensure it does not swell. We use a spiral bind machine to bind the pages of the booklet with a cardboard backing, so that the booklet lays flat but remains sturdy and allows Maddy to keep the page she needs open.

4.3 Lab Accessibility

Beyond adapting individual pieces of equipment, we aim to make lab itself accessible. This includes both interventions to support Maddy in *navigating* the space and to ensure that the materials she needs to practice and record are consistent and *reachable* (Figure 6).

4.3.1 Navigation. To support nonvisual navigation, we adapted the lab with low cost materials and we implemented policies for all users. We applied grip tape on the floor in front of synthesizers that Maddy uses so that she can easily detect them with her white cane. Of course, grip tape becomes a useless signifier if a synthesizer is moved or obstructed by clutter. So, we attached sparkly gemstones on the backs of chairs and matching gemstones on the tables where they belong so students would be reminded to return chairs to their correct places. To further promote safety and consistency, we posted signs reminding students to return furniture and equipment to their assigned places. These policies are also listed at the top of the Audio Lab website.

4.3.2 Reachability. We made a few simple, low-tech changes to aid Maddy and others with operating the synthesizers in a seated position and via touch navigation. Before the SynthAccess

Figure 6: One wall of the synthesizer lab. The chair and table include matching red glitter tape indicating where the chair belongs. A patch cable rack is mounted on the front of the desk promoting reachability.

project, patch cables were hung on the wall behind and above synthesizers. Obtaining cables required visually locating them, standing up, and reaching. This method was not effective, so we attached a patch cable rack to the front edge of desks, enabling seated students to easily reach the cables at desk-level. We also mounted USB cables to the sides of synthesizers. Finally, we located a simple roller desk for Maddy to place her tactile reference booklet when operating a corresponding synth.

4.4 Maddy's Experiences with SynthAccess

To date, progress has been positive. Maddy continues to experiment in the Audio Lab, and the team is eager to continue co-designing accessibility solutions. Our varied approaches work in tandem towards empowering Maddy. For example, consistent room layout and cable management systems are helping Maddy use the space independently. They promote a creative environment in contrast with other music spaces at NYU that lack similar policies. In other studios, Maddy must locate and set up her workstation, including installing braille overlays and configuring AT from scratch. In our lab, Maddy does not need to use as much mental energy and time just to set up, allowing her to be creative and get into a flow state. The tactile booklets have been helpful for reinforcing Maddy's understanding of the layouts of synthesizers on a per-module and per-board basis, even when she is not in the lab. They remind Maddy in between sessions how synthesizers are laid out at both a high and low level via the maps and detailed module pages. In the lab, their fixed location allows her to refer to them while she is using the synthesizers or planning new configurations. Finally, Maddy finds the speech synthesis tool especially useful because it proactively tells her the name and values of controls the instant she touches them rather than requiring her to consult separate reference materials, which can break creative flow. However, the speech synthesizer will stop talking if her computer goes to sleep and is less reliable than the tactile booklets.

4.4.1 Ongoing Challenges. Remain challenges that we have yet to overcome, relate to debugging and patch cable management. First, when Maddy is trying to edit a patch to achieve a certain sound, she must feel every control on the synthesizer to identify potential sources of the sonic discrepancy. Because she interacts with controls through touch and does not see everything at once, it is tedious and cognitively demanding to piece together a macro-view of the synthesizer's state. Second, synthesizers that require extensive cable management take significant mental effort to track signal flow without seeing it. Our reference documents are static, and do not show emergent patch configurations, and the speech synthesizer does not (yet) verbalize patch cable placement. While patch cable configurations are difficult for many users to follow, Maddy also does not benefit from visual aids like differently colored cables or user-generated patch diagrams, (though textured cables are worth pursuing as an alternative). In cases where Maddy estimates there are five or more patch cables, she has asked TAs to aid in describing their arrangement.

5 Discussion

Our multifaceted approach has been successful at promoting inclusive practices in the lab and ensuring Maddy can both use synthesizers independently and with others. In this section we discuss ongoing design tensions, and our vision for partnering with industry to expand the impact of this work.

5.1 Design Tensions

As our team implemented designs across non-visual modalities, we repeatedly ran into tradeoffs balancing workflow, object reliability, and complexity. For example, our tactile overlays use both laser cut acrylic and hand-applied braille labels. Laser cutting is durable and repeatable but requires specialized equipment. Hand-applied braille is cheap but slow and hard to reproduce. Additional explorations to automatically add braille and tactile signifiers, via swellform or UV printer, have the potential to promote durability and replication. However, adding more fabrication tools makes the workflow harder and limits who can reproduce it. As we share our designs and production methods with other synthesizer groups and organizations that work with BLV musicians, we will include both low-tech and high-tech strategies for adapting synthesizers.

An additional design challenge we encountered is the information density and precision of tactile signifiers. For individuals devices, we are constrained by space. For example, while ARP's original intent in releasing the 2600 with signal flow diagrams was to expose underlying behaviors and to teach synthesis, we could not even fit full braille text on the device. We overcame space constraints by identifying which tactile signifiers belonged on hardware and which could be offloaded to reference booklets. At scale, when we aim to create consistent resources for many synthesizers, we are constrained by cognitive load and the ability of Maddy (and future users) to remember the meaning of symbols and vocabulary. Here, we note a tension between representing the physical properties of an affordance, and its underlying behavior. For example, designing a new symbol for each uniquely-shaped power button is not practical, and we do not want to overwhelm with many types of symbols for an affordance with the same function. Knowing when to create new symbols to accurately represent unique features of different hardware is an ongoing challenge. Relatedly, the speech synthesizer could be improved with further customization options. Currently, the only available setting is rate-of-speech. Support for verbocity, or the amount of information conveyed at each utterance, could reduce unnecessary clutter that interferes with synth output. It would also promote effective use in scenarios where different

Figure 7: Maddy using the Sequential Prophet 6 with a braille overlay and laptop running speech synthesis software.

levels of information are necessary, including learning, mixing, and live performance.

5.2 Promoting Accessibility at Scale with Industry Partners

We are at the early stages of collaborating with companies that manufacture synthesizers, and have shared our designs extensively with the internal product teams at the Focusrite Group, which has a number of subsidiary synthesizer brands. To successfully use digital access tools such as our speech synthesis system, companies must ensure that all control values, particularly those conveyed via screen, can be accessed via MIDI. Not only will this allow us to implement effective speech synthesis software, it enables a wide variety of accessibility efforts. For example, Deaf and Hard of Hearing users could connect haptic output devices to follow multiple sources. People with motor impairments could connect input devices, like switches, joysticks, that work for them, to get past tiny knobs and buttons. Resources for understanding how to access these values, including clear documentation and working code examples, are also crucial in ensuring that new users with disabilities and not just experts are able to modify their devices.

In many cases, the burden of accessibility falls outside the manufacturer. This is particularly true when creating braille labels and tactile guides for well-documented legacy synthesizers such as the ARP 2600, or with small-scale and DIY manufacturers, where a robust user community could step in to support this work. As with the expectations of sighted users of our lab, we view synthesizer access through an interdependence lens [4] where companies, educators, open-source designers, and musicians play a role. Flo Tools offers one music technology example of a productive company/open-source relationship [6]. Avid, the developer of ProTools committed to ensuring its GUI would be exposed to screen readers and other AT. However, because basic interactions, like checking playback time, remained laborious [26], an open-source team of BLV developers then built additional interaction methods to improve screen reader and keyboard-based workflows. While Avid's commitment to accessibility has enabled community input, the relationship could still be percieved as exploitative, with a profitable company offloading design labor to volunteers. Ideally, synthesizer companies will share more to support accessibility efforts, including financial commitments. We see this relationship as going both ways: our designs are entirely public and open-source, complete with style guides and other resources for developing overlays, tactile guides, JSON configuration files, etc. Collaborations could support future initiatives similar to the Moog Phatty braille edition [9] that provide an expanded user market for manufacturers. The ultimate goal would be for these systems (and others like it) to be incorporated into mainstream product design considerations as part of an industry-wide commitment to accessibility.

6 Limitations and Future Work

This research takes place within a university setting and is primarily guided by one blind collaborator. As a result, we cannot make broad claims about the accessibility of our artifacts in other contexts. In the near future, we are pursuing three directions to expand and validate the impact of SynthAccess. First, we will continue to create braille overlays and tactile reference booklets for synths in our laboratory. We are implementing a web-based version of our speech synthesis tool and exploring mechanical braille outputs. Second, we plan to work with sighted designers and synthesizer enthusiasts outside our university to create tactile reference booklets for other devices. The results will expand our open-source collection of accessible materials and will be used to improve our style guide. Finally, we view this work as a precursor towards improving the accessibility of *teaching* analog synthesis. We plan to design lesson plans and curricular materials that include a combination of listening/performance and synthesis foundations [12] and lead workshops with BLV adults.

7 Conclusion

SynthAccess was motivated by a need to make our university synthesizer lab more accessible in partnership with a blind music student and technologist. In this paper, we report on our collaborative efforts to date, which include fabricating braille overlays for the synthesizers, iteratively designing tactile reference booklets, and writing laboratory policies to promote inclusive behaviors of all users. While we continue to address challenges, like cable management and workflow complexities, we are excited to continue designing interventions. The concept of SynthAccess goes well beyond our lab. Moving forward, we will partner with other blind and sighted colleagues to improve our open-source repository of open-source materials.

8 Ethical Standards

In this study to improve synthesizer accessibility, a core member of the team is disabled. Following the widely-used slogan from Disability Rights activists, “nothing about us, without us,” every all work phases involve her, including problem identification, design methods, evaluation, and reporting. While Section 4.4 is written in the third person to identify this member by namer, she led its writing and contributed to the rest of the paper. Furthermore, our work is not done with this article. We are committed to continuing our efforts and releasing all materials as open source files to the public. A limitation of research to date is that most design efforts have been motivated by one blind individual and may not scale to all circumstances. Vision loss is wide-ranging and only one part of a whole person. Future studies will go outside our lab to engage with broader BLV community members.

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