Harmonising the Senses

An Inclusive, Multi-Sensory Design Journey
Co-Created with Visually Impaired Participants

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A dissertation submitted in partial fulfilment of the requirements for the degree of Master of Arts

By

Elgee van Tonder

Contents

Preface

The dissertation proposes an inclusive multisensory design approach based on co-design approaches with the blind and low vision communities, stressing that accessibility must not be an afterthought nor an add-on feature. This work has therefore been typeset in a font chosen not for conformity to institutional norms, but for legibility: the argument of this dissertation would not be compelling were it otherwise. For this reason, I use Atkinson Hyper legible throughout, where the institution requires a different font. Not as a question of form or aesthetics, but of aligning form with content, practice with principle.

Atkinson Hyper legible was designed for the Braille Institute by Applied Design Works, for readers with low vision. The Braille Institute (2019) explains that while typefaces are often influenced by aesthetic principles, every letter form and letter pair in Atkinson Hyper legible was constructed for minimal legibility overlap, i.e., to maximise the opportunity for a reader with low vision to precisely recognise each letter.

Choosing to use Atkinson Hyper legible is only one small step among many in making the work accessible to readers, along with screen readers, alt-text for figures and a logical hierarchy of headings. Nevertheless, choosing Atkinson Hyper legible is a conscious gesture of practice-based integrity, a step towards making academic publishing more open, and a way to remind us all that design choices in communicating knowledge do make a difference.

Introduction

While guidelines such as Universal Design exist (Center for Universal Design, 1997), design and development practices have room for improvement, mainstream games still vary widely in their accessibility for blind or low-vision players. According to the RNIB's Accessible Gaming Report (2022), 76% of gamers with sight loss reported their condition significantly impacted their ability to play, while only 15% of game developers reported a sufficient understanding of their needs — a gap that reveals how far design practice has to travel (see Figure 1). Accessibility is often discussed in terms of superficial features like ramps, font size, or colour contrast, but cross-sensory design is under-explored, particularly regarding the inclusion of blind and low-vision participants in the design process. This is especially true in play and leisure contexts, such as board games, toys, and other forms of play media. This dissertation therefore explores how blind and low-vision people play with and within physical play. Whereas research into accessibility in digital play is growing, the inclusion of blind and low vision audiences in the design of physical play experiences, including board games, toys, and other interactive play has received less attention.

Figure 1: The Accessibility Gap in Physical Play

Players Affected

76% BLV gamers say their sight condition significantly impacts ability to play

Developer awareness

15% Game developers report sufficient understanding of BLV gamers' needs

Source: RNIB Accessible Gaming Research Report (2022)

Research Problem and Aim

The problem my research responds to is twofold:

1. Inclusive design principles are not always applied consistently in ways that meaningfully serve BLV users.
2. Multi-sensory design methods; approaches that combine or substitute across sound, touch, and vision remain underutilised in game and product design.

The aim of this project is to explore how multisensory design can harmonise tactile, auditory, and visual cues to create inclusive, engaging experiences. This exploration takes shape through the co-creation of a **musical block game**, developed in dialogue with BLV participants. By stacking tactile blocks, players can construct melodies that are translated into sound. This design journey is not only about producing a playable prototype but also about generating knowledge through making, reflecting, and co-designing.

Research Questions

This dissertation is guided by the following questions:

1. What inclusive design principles can make design more accessible to blind and low-vision users?
2. How can multisensory methods be used in design to create accessible outputs for blind and low-vision users?

They ask the theoretical question of how these principles are relevant, and the practical question of how they can be executed through material prototyping and co-creative game design practice based on these principles.

Research Approach

This project made use of a participatory design approach (Sanoff, 2007) whereby BLV participants acted not simply as research subjects for data collection but co-designers throughout the process.

- Ashley wanted to avoid clutter, leading to simpler, recognisably block-like shapes.
- William's parent stressed the importance of simplicity and durability in toys.
- Jeff stressed the importance of audio panning and haptic feedback in the game.

This resonates with Design Justice (Costanza-Chock, 2020) and the idea that design should come from lived experience, not be imposed from above, and should be done with BLV people, rather than under the assumption that universal design would be appropriate for this population.

Literature Review

Inclusive and Universal Design Frameworks

While universal design and inclusive design are different terms with different histories and goals, they share the common goal of increasing access. The focus of universal design of everyday things, environments, and services is to make them usable by as many people as possible without requiring them to make adaptations (Prandi et al., 2021). Inclusive design accepts that there is not one solution for all and creates designs that aim to be as inclusive as possible for the general population, but that may require compromises to be made in terms of business requirements or target solutions for specific parts of the population.

When designers use inclusivity and accessibility frameworks (such as WCAG, Universal Design, and Inclusive Design), the principles in the framework align with the five objectives, which are comparable experience, consistency, user control, choice, and content-first (W3C, 2018). Empirical studies and case studies have confirmed that these methods have been successful in improving usability, and they continue to be used in visual communication and graphic design.

Universal Design (UD) is a conceptual framework that first came out of the field of architecture (Center for Universal Design, 1997). However, UD has been applied to accessible product and environmental design for the widest range of users. To better understand what Universal Design is, UC Davis' Center for Universal Design (1997) has defined UD by the following seven principles: **equitable use, flexibility in use, simple and intuitive use, perceptible information, tolerance for error, low physical effort, and size and space for approach and use** (see Figure 2). Fairness for all means that sighted and blind players may play the same game, flexible use means playing with tactile or auditory information, or both. Perceptible information means, for example, redundancy, meaning that the information may be perceived in a number of ways (texture, sound, vibration). These principles argue for blocks that can be connected easily and have fast auditory feedback, minimising both physical stress and errors.

Inclusive design builds on the principles of universal design, but recognises that this one size does not fit all. Building on this, co-design with diverse BLV participants in this project confirmed that no two experiences of blindness or low vision are alike, requiring a flexible rather than prescriptive design approach. This work has also highlighted the diverse experiences, understandings, and needs of people with BLV. As such, the design of these systems needs to be multi-modal, allowing for customisation of tactile and auditory feedback. Tactile objects should be simple and obvious, as complex designs might interfere with tactile awareness. The success of inclusive design relies on collaboration between various disciplines and testing with the user community. Tactile Graphics and Tactile Literacy BLV makers must choose between accessible, low-fidelity craft materials and inaccessible, high-fidelity equipment. The paper calls for future tactile graphic systems that are ubiquitous, expressive and accessible, empowering BLV people to design and produce them. It also notes that BLV creators often use low-tech, craft-based materials such as rubber boards, yarn and pasta to produce tactile graphics on the fly. These insights support the use of tangible materials like osteomorphic inspired blocks in our game and suggest exploring user-customisable components.

Tactile literacy, or the ability to interpret tactile graphics, is learned through varied touch experiences. Real objects and 3D models serve as “stepping stones” to understanding tactile representations. Engagement with tactile graphics is driven by the meaningful experiences they enable rather than the graphics themselves. Therefore, the design of tactile game elements must provide clear, distinct textures and align with meaningful actions such as composing melodies or constructing shapes.

Tactile Graphics and Tactile Literacy

Tactile graphics translate visual information into raised line drawings and textures that can be read by touch. Rong et al. (2025) highlight that while tactile graphics are highly valued by BLV individuals, current methods of production are labour-intensive, inaccessible to BLV creators and often produce low-quality results.

Figure 2 — The Seven Principles of Universal Design

INTERACTION DESIGN PRINCIPLES

EQUITABLE USE

The design is useful and marketable to people with diverse abilities.

FLEXIBILITY IN USE

The design accommodates a wide range of individual preferences and abilities.

SIMPLE AND INTUITIVE

Use of the design is easy to understand.

SENSORY DESIGN PRINCIPLES

PERCEPTIBLE INFO

The design communicates necessary information effectively to the user.

TOLERANCE FOR ERROR

The design minimizes hazards and the adverse consequences of accidental or unintended actions.

LOW PHYSICAL EFFORT

The design can be used efficiently and comfortably and with a minimum of fatigue.

PHYSICAL DESIGN PRINCIPLE

SIZE AND SPACE FOR APPROACH AND USE

Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.

Source: Center for Universal Design (1997). https://design.ncsu.edu/wp-content/uploads/2022/11/principles-of-universal-design.pdf

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Multisensory Interaction and Sensory Substitution

Multisensory design leverages multiple senses to convey information. Cho (2021) suggests that multisensory interaction aids learning, inclusion and collaboration because it accommodates diverse cognitive and perceptual needs; conventional human–computer interaction devices are inconvenient for visually impaired people due to their reliance on visual information.

Cho’s review also discusses synaesthesia and weak synaesthetic correspondences, suggesting that deliberately associating tactile textures with auditory qualities can foster richer sensory experiences. These insights align with my aim to create consistent cross-modal mappings.

Participatory Design and Design Justice

Participatory design treats users as co-designers. Costanza-Chock’s Design Justice critiques universalistic design as taking intersectionally disadvantaged populations and rendering them invisible. Design must explicitly account for how its benefits and harms are distributed across lines of race, class, gender and disability. The design justice framework states that design should be led by the people most affected and that they should own the design outputs, because without control over the design process, good intentions and design can systematise existing inequities (Costanza-Chock, 2020). It also warns against micro-aggressions in design, with systems encoding small unintentional indignities that remind marginalised users of their subordinate status (Costanza-Chock, 2020).

In a design justice process, BLV people can participate from the earliest stages of game design to prototyping and making design decisions regarding a game's textures, sounds and interactions. Design justice also implies thinking about the game design for BLV players at different levels of visibility, identity and intersectionality, as for example a blind person with a physical disability.

Inclusive Game Design

Research on inclusive games emphasises auditory feedback as the primary method for conveying information to blind players (Deng, 2024). Sound cues provide spatial awareness and indicate the position of game elements. Text-to-speech (TTS) and voice navigation technologies offer verbal information and guidance. Inclusive game designers recommend involving blind gamers in testing and design to identify accessibility challenges and refine mechanics (Deng, 2024; Rong & Hansopaheluwakan-Edward, 2025). For my musical game, these insights mean designing sound feedback that communicates pitch and correctness without relying on vision, and integrating voice prompts to guide play.

Co-Design & Blind-Led Methodologies

Design with the ambition to be inclusive cannot be solely guided by the viewpoints and beliefs of sighted designers. Advocates of design justice maintain that the formulation of design should be directed by the individuals who experience its effects most profoundly (Charlton, 1998). Instead of employing empathy exercises or disability simulations, which merely provide individuals with a glimpse into the experience of living with a disability and often evoke pity (Silverman et al., 2015), blind-led co-design empowers blind and low-vision (BLV) individuals to take the lead in their own sensory environment. This philosophy aligns with other insights into graphic design that is excessively concentrated on visuals. These insights encourage the acknowledgment of non-visual literacies (Kleege, 2005/2014) and viewing design as a means to foster understanding (Gillieson & Garneau, 2018).

Rationale and Ethics

The project was an opportunity for co-design, also called participatory design. It allowed BLV participants to be co-designers that lead the direction of the work rather than being given what might be “accessible” to them. Participants were asked to talk about games, toys, and household items that they interacted with. This process showed how metaphors and design conventions which are fit for customary interfaces do not generalise. The insights gathered illustrated that visual metaphors like hot and cold colour associations do not transfer when the sensory reference point is touch or sound. BLV players may know the sensation of trailing their finger along a rough surface, for instance, or the sound of a pedestrian crossing signal that indicates when it is safe to cross. These hints are a reminder of the importance of allowing the sensory communications of blind players to take precedence over our visual explanations.

In a liberating approach that took design justice into account, my project sought input from affected people/communities as collaborators, not just consultants (Costanza-Chock, 2020). This involved an interview process that worked to allow the interviewees to prioritise their own stories and agenda in the process of gathering the information. Questions were reworded, described without visual reference and not over-explained. One interviewee, after hearing the word “imagine”, gently reminded me that imagination is not only visual. Another participant was blind for six months, and discussed the challenges of being sightless in the world. This lived experience helped convince me that I, as the designer, didn’t understand, in fact, was the problem, and argued for the importance of participant leadership to ensure inclusive design that can lead to meaningful outcomes.

Using a practice-based approach (Frayling, 1993) and drawing on participatory design principles, this research treats the act of making artefacts as a form of knowledge generation; I learned through making, iterating and reflecting. To address this, techniques like participatory design were used. With participatory design, the knowledge and experience of participants are prioritised, meaning the designer collaborates with the users, rather than designing for them (Sanoff, 2007, p.213). It is also particularly useful in a design field where visual literacy is implicitly assumed (Mussi et al., 2019). Previous research suggests that BLV people perceive information about space from non-visual channels, such as touch, hearing, and the kinaesthetic sense, and deal with way finding problems (Lloyd-Esenkaya et al., 2020). It sought to draw upon the feedback of BLV participants throughout to create design principles and a multi-sensory game prototype.

Participants and Recruitment

Eight primary interviews were conducted with BLV adults, caregivers of BLV children and two professionals from a specialist school(BLENNZ). Participants ranged in age from approximately four (represented by caregivers) to late fifties and included people blind from birth, those with congenital glaucoma, cortical visual impairment, and one recent stroke-related vision loss. Recruitment was purposive: New Zealand participants and international participants were recruited via Facebook support groups. Interviewees included:

- **Jowairya Soliman:** a university student from Egypt with congenital glaucoma.
- **Guy Marrais:** a former business developer in his late fifties from Switzerland., blind following a stroke, who misses reading and accessible games.
- **Jeff Boudwin:** blind since age three and working as a child therapist — not yet fully certified in play therapy at the time of interview.
- **Ashley Sheperd:** 26, a New Zealand designer and disability advocate with cortical visual impairment and right hemiplegia, whose feedback on contrast, tactile simplicity, and dexterity directly shaped the block design.
- **Becky Johnson:** mother of William (age9) has low vision due to congenital glaucoma.
- **Karen Plimmer:** in her forties, legally blind since birth but able to perceive light/dark; former disability funding advisor and aspiring postgraduate music student at University of Auckland.
- **Julie Herbert:** caregiver of Ryan (age 23), who has cortical blindness, cerebral palsy and epilepsy, and explores art through sound and raised geometry.

- **Debbie Kokay:** grandmother of Anthony, a four-year-old with CVI, deafness, epilepsy and global developmental delay.
- Additional consultations were held with **Anthony Frost** at BLENNZ, who provided advice on prototype adjustments.

Data Collection

The primary data collection method was **semi-structured interviews**, conducted online via video calls. Each interview lasted about 60minutes and explored participants' everyday experiences with games and design, their sensory preferences, and reactions to early prototype descriptions. No formal co-design workshops were possible due to participants schedules and the researcher's overseas secondment; however, prototype play testing sessions were arranged informally with BLENNZ staff and caregivers. Audio recordings were transcribed using Otter.ai and imported into Notion for coding. Field notes captured non-verbal reactions and details about tactile interaction with early prototypes.

Initial blocks incorporated magnets and were designed to snap together and trigger musical notes. Feedback on these early models highlighted safety concerns (sharp edges on resin prints) and usability issues (hand-held colour scanners risked knocking over towers), which informed later iterations .

Data Analysis

Thematic analysis was applied to the transcripts and field notes following Braun and Clarke's (2006) six phases: familiarisation, coding, searching for themes, reviewing themes, defining themes, and producing the report. The interview transcripts were read and statements highlighted and coded into literature-based themes of multisensory stimulation, simplicity and clarity, social play, and customisation and flexibility. This was then organised into larger themes based around the inclusive design principles established in the literature review, and then written into design guidelines for the prototypes. This ensured that the generated findings were rooted in both the data collected and the literature, as well as giving them a concrete form.

Ethical Considerations

Ethical approval was obtained from the Wintec Ethics Committee. Participants provided informed consent verbally at the start of each interview. To respect the principles of blind-led design, interviewees were encouraged to lead the conversation and to challenge any visual metaphors or assumptions. Visual terms such as “imagine” and other sight-centric vocabulary after early interviews highlighted how such language can exclude BLV participants . No significant ethical dilemmas arose; however, the interview protocol evolved as more insight was gained forming a deeper understanding of participants’ experiences.

Evaluation Strategy and Limitations

The original plan was to conduct formal usability testing with the final prototype, using observation and Likert-scale measures of **usability, enjoyment,** and **inclusivity.** Time constraints and a redesign—from a hand-held scanner to an embedded resistor system—prevented full evaluation. Early playtests at BLENNZ were nevertheless valuable: Aaron Frost (BLENNZ Hamilton Manager) found the hand-held scanner unstable and preferred snapping blocks that provided clear tactile and auditory feedback . These insights led to the development of a “baseplate” board and blocks that click and snap together, unfortunately no quantitative data were collected. Future work should include systematic testing with a larger group of BLV players.

Tools and Tactile Prototyping

The co-design also highlighted the limitations of mainstream design tools. Many digital design production tools remain inaccessible to BLV users, including those used for creating tactile graphics and visual assets (Clepper et al., 2025), making it difficult for them to participate in early ideation. To circumvent this barrier, the project relied on physical prototypes. 3D-printed blocks allowed participants and educators at Blind and Low Vision Education Network NZ (BLENNZ) to explore shape, texture and magnet placement directly. Hands-on prototypes exposed issues that digital simulations could not: resin prints were found to be unsafe, leading to a switch to FDM printing; magnets needed to "click" clearly to provide auditory confirmation; and high-contrast colours were included for those with residual vision. The tactile LEGO like baseplate used in BLENNZ classrooms also inspired the decision to design a stationary board, rather than a hand-held device, to minimise the risk of blocks being knocked over and to provide a shared spatial reference.

Iteration, Feedback and Change

Multiple iterations emerged from these tactile engagements. Early concepts envisaged a hand-held colour scanner that would read the height of a tower, but feedback from teachers and students revealed that children learn spatial relations through tactile boards and that a hand-held device could introduce confusion. Co-designers recommended simplifying block shapes to aid recognition and using textures, colours and shapes to signify different functions. They also stressed that audio feedback should be immediate and intuitive—much like the universally recognised beep of a pedestrian crossing—which led to rethinking the magnet concept and the pitch of the sounds produced. Without such input, the game might have remained an abstract experiment in sensing, disconnected from the ways BLV children actually play and learn.

Beyond Collaboration: Challenging Norms

Co-design in this project was not simply a matter of ethics; it produced better outcomes. By letting BLV participants lead, the resulting game addressed real needs and desires rather than imagined ones, aligning with research that highlights the social aspects of game accessibility. The process also challenged conventional graphic and product design work flows. In academia and industry, designers often receive briefs from clients and translate them into products without questioning the underlying assumptions. Working with BLV communities revealed how narrow this approach can be and suggested that educators and designers should allow students and users to guide topics and solutions. This perspective echoes broader critiques that see design as a site of cultural critique and inclusivity. By foregrounding blind-led methodologies, the project contributes to a shift from designing *for* disabled people to designing *with* them, reinforcing the principle that inclusive design benefits everyone, not only those with permanent impairments.

Findings

The findings presented here synthesise the voices of participants and caregivers with the insights from the literature. They reveal recurring patterns in how BLV individuals experience games and design, and they highlight design opportunities for creating inclusive multi-sensory play.

Code	Theme
Clear audio feedback	Multisensory Engagement
Distinct tactile surfaces	Multisensory Engagement
High-contrast colour	Multisensory Engagement
Simple mechanics	Simplicity and Clarity
Uncluttered interfaces	Simplicity and Clarity
Sensory overload concerns	Simplicity and Clarity
Desire to play with sighted peers	Inclusive Social Play
Isolation from mainstream games	Inclusive Social Play
Open-ended creative expression	Customisation and Flexibility
Adjustable feedback	Customisation and Flexibility

Multisensory Engagement

Participants repeatedly emphasised the importance of **clear audio, distinct tactile feedback** and **high-contrast colours**. Jeff noted that he snaps his fingers to gauge the dimensions of a room through echo, relying entirely on non-visual cues when navigating unfamiliar environments and games (Jeff Boudwin, personal communication, 2025). Guy remarked that he misses reading and playing games, while chess's distinct sizes made pieces easy to identify. Ashley and Becky both underscored that simple shapes and uncluttered layouts make games manageable for children with cortical visual impairment and glaucoma. Julie explained that her grandson Ryan explores art through sound and raised geometry, and Debbie said that anything that "hits the senses" is huge for Anthony.

The design responded to these insights by developing musical blocks that snap together, providing a satisfying tactile confirmation, and play notes when stacked, allowing players to build melodies through touch, operationalising principles of multisensory design (Cho, 2021; Lloyd-Esenkaya., et al 2020). Colours such as cyan, magenta and yellow on dark platforms were chosen because participants reported they are easily distinguishable for those with residual vision. Vibration feedback was also considered after Debbie described how Anthony enjoys anything that vibrates, this proved to be more complicated and will be considered for future iterations/explorations.

Simplicity and Clarity

Caregivers and BLV adults stressed that games must be simple, uncluttered and easy to understand. Becky observed that William benefits from straightforward mechanics and immediate tactile or auditory feedback rather than complex rules. Ashley Sheperd similarly noted that she cannot filter ambient sound — hearing everything simultaneously — and that sensory overload causes cognitive shut-down comparable to experiences described in autism research (Ashley Sheperd, personal communication, 2025). This reinforced the need for controlled, non-overwhelming audio design across a range of BLV experiences. Ashley described how patterns like polka dots and stripes can blur objects together, while

Karen explained that she always imagined the sky as a flat sheet until AI descriptions revealed more detail. To address this, the game avoids cluttered interfaces, uses a limited set of block shapes, and provides audio guidance instead of a printed rule book.

Inclusive Social Play

Another theme was the desire for inclusive, family-friendly play. Several participants lamented that accessible games often segregate blind players or require special adaptations that sighted friends cannot use. Debbie emphasised that Anthony needs social interaction and that current sensory toys feel isolating. Karen Plimmer similarly highlighted that accessible games could play a vital role in developing social skills for BLV children — particularly turn-taking and peer engagement — if the accessibility barrier is removed from the outset, allowing disabled and non-disabled players to participate on equal footing (Karen Plimmer, personal communication, 2025). The design therefore aims to be universal—engaging sighted and blind players alike. Blocks are intuitive to handle; stacking them produces music that anyone can enjoy. By keeping the interface simple and relying on auditory and tactile cues, the game enables cooperative play without special accommodations, fulfilling the principle of equitable and flexible use (Center for Universal Design, 1997)

Additional Insights and Surprises

Although most findings confirmed expectations—such as the need for multi-sensory feedback—a few nuances emerged. Participants demonstrated strong emotional connections to music; Guy remarked that heavy metal was psychologically important to him, suggesting that musical genre and tone can influence engagement. Julie noted that Ryan scrolls through songs by using his nose and drums along by ear, hinting at inventive ways BLV children interact with technology. These insights suggest future design work could allow users to customise musical scales or rhythms to reflect personal preferences..

Synthesising Principles

The themes above map neatly onto the inclusive design principles proposed earlier.

- **Empathy & user-centred co-design.** The research methodology actively involved BLV participants in defining problems and solutions. Conversations were led by participants' experiences, ensuring their perspectives shaped design decisions .
- **Multisensory & tactile engagement.** Interviews underscored the importance of audio and touch in conveying information. The prototype therefore combines tactile stacking with auditory feedback (Cho, 2021; Remache-Vinueza et al., 2021) — drawing on principles from both BLV and hearing-impaired inclusive design research.
- **Safety, clarity & simplicity.** Feedback from caregivers informed the simplification of block shapes and avoidance of hand-held scanners. High-contrast colours and uncluttered layouts support perceptible information and ease of use.
- **Customisation & flexibility.** Although not fully realised, participants expressed interest in adjustable feedback and the ability to progress from simple melodies to more complex rhythms. Future work could allow users to choose scales, volumes or timbres.
- **Inclusive & universal benefits.** By designing a game that sighted and BLV players can enjoy together, the project illustrates how inclusive design can benefit all users (Deng, 2024), not only those with disabilities.

This synthesis demonstrates that the findings are not only grounded in empirical data but also align with established inclusive design frameworks. The next steps involve refining the prototype based on these insights and conducting formal evaluations to validate the game's accessibility and appeal.

Interpreting Findings and Implications for inclusive design

This study intended to gain perception on how multisensory design can support people who are blind and have low vision (BLV) to play together in an inclusive and enjoyable way by creating a musical block game (*Sound Stack*). The results of the thematic analysis identified three themes: a need for multisensory integration; a simplicity-complexity tension; and a need for socio-emotional interaction. The writing relates these findings to the existing literature and, in particular, to matters of design practice.

Multisensory Integration as Design Language

The findings show that multisensory integration is more than a technique to compensate for visual impairment—it is a design language that BLV people use to make sense of the world. Participants explained that sensory modalities transmit semantic information, much as sighted individuals understand visual signs and symbols. People who are blind or have low vision (BLV) have learned to adapt their other senses. They interpret sounds, touch and texture in nuanced ways.

This discovery builds on Cho's (2021) notion of multisensory interaction, which emphasises cross-modal connections and sensory replacement. While Cho (2021) explores both sensory substitution and cross-modal integration, the present study found that BLV participants strongly favoured integration over substitution (see Figure 3). The musical block game puts this principle into practice by delivering information through multiple channels. The click provides security and placement through touch and sound. Audio cards offer spoken instructions, eliminating the need for a printed rulebook — an idea proposed directly by Jeff Boudwin, who suggested scannable cards with voice instructions and recommended that sound feedback be toggleable to avoid overwhelming players (Jeff Boudwin, personal communication, 2025). Blocks have distinct shapes and textures to indicate their function. High-contrast colours support players with residual vision. These modalities work together to create an enjoyable sensory experience that does not privilege one sense over another.

This approach differs from the conventional view that audio descriptions are simply add-ons to visual designs. The findings demonstrate that accessibility is not about removing vision—it is about offering people with BLV multiple ways to access information that align with how they naturally learn. For example, a pen click signals that the pen is ready to write, a detail that sighted users might overlook. The satisfying snap of the game blocks confirms correct placement, giving William the reassurance he needs.

Simplicity and Richness: Reframing Accessible Design

Another theme is simplicity versus novelty; Ashley said that “polka dots and stripes blur objects together”, while William’s mother Becky said “simple, uncluttered games work best”. In contrast to this, Guy said heavy metal music was “psychologically important” to him and he was emotionally attached to it. Julie Herbert noted that Ryan demonstrated a striking level of musical engagement, sometimes scrolling between music tracks with his nose and drumming along by ear (Julie Herbert, personal communication, 2025). The question arises about whether simplicity and complexity are complementary or conflicting design themes in information systems.

This is not a conflict, rather a misuse of the term “accessible”: in inclusive design simple is not necessarily easy or basic. Guy had enjoyed chess before his stroke and suggested during the interview that magnets embedded beneath the board could allow pieces to be held in place — a practical adaptation insight that informed the magnetic block design (Guy Marrais, personal communication, 2025). His rehabilitation confirmed that perception of structure and interaction with the environment need not depend exclusively on visual or tactile information. This is supported by a simplified musical block game system (including the number and shape of the blocks, and regular tactile markings) and opportunities for creative play through music creation, discovery and co-play.

The BLV person needs information to be presented through one sense at a time in the least distracting way while not disallowing interactions. These conditions imply that what improves a thing to be interactive and rich is not the large number of its functionalities, but the high degree of its structured complexity and layered interaction.

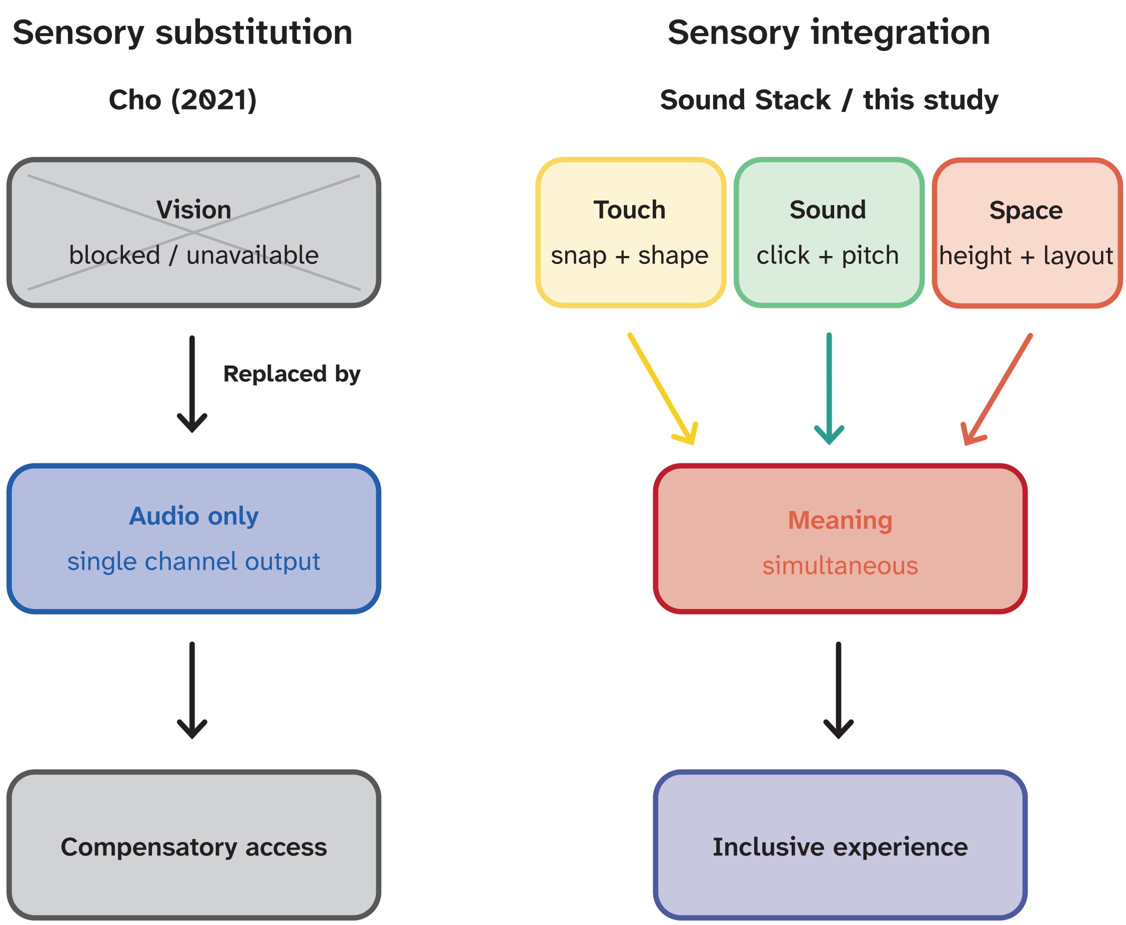
It has consequences for standard practice in design. The phrase “accessible” normally comes with a stigma of “dumbed down”, and inclusive design is somehow assumed inferior to the mainstream. An accessible game could be as easy as removing the obstacles in the game or it could be creating everything in the game with accessibility from the start. Sound Stack does not accomplish this through the ability for completing the game elements easier than they normally would be. The challenges of the game using tactile hierarchy, auditory feedback and physical interaction show that accessibility design can be advanced and enjoyable.

Social Inclusion: Challenging Segregated Accessibility

An additional barrier was social. Anthony’s grandmother Debbie said “He needs social interaction” because Anthony didn’t gain enough social stimulation from the sensory toys. Other games available to Anthony were parallel games (e.g. Braille board games, or games involving a sighted player acting as a game master) because board games use text, colours, the layout of the game pieces, and so on to communicate essential information to players and the players need to understand the game. However, BLV players rely on sighted players to read cards and describe game moves and therefore experience unequal participation, less autonomy, and fewer social and developmental benefits from play than other players may experience.

One exception to this is the same-system multiplayer game *Sound Stac*k, which allows sighted and blind players to use the same system. There is no “blind version” or “adapted version” of the game; the blind get textures, the sighted get visuals and both get sound. Related to the Universal Design principle of equitable use, accessibility is built into level design rather than additional; the stacking of blocks allows blind and sighted players to play collaboratively without the need to share the same visual elements, instead focusing on how each experience the game through the tactile, aural and social aspects of its gameplay. These findings show that social interaction is not a "nice-to-have", but an essential part of human existence. The lack of inclusive games is not just a void in game design, but also a social injustice against BLV people, who are generally marginalised in other recreational forms. To fill in this gap a collaborative game with BLV users was created to play. Music had a clear advantage over other modalities as it is a universal language with many of

Figure 3 — Sensory Substitution vs Sensory Integration Diagram



Sources: Cho (2021) — substitution model. Lloyd-Esenkaya et al. (2020) and this study — integration model.

Figure 3: The theoretical shift from sensory substitution to multisensory integration in Sound Stack.

the same properties as mathematics, making it a good sensory modality agnostic game/activity for a wide range of audiences.

The project further illustrates all seven principles of universal design: equitable use; flexibility in use; simple and intuitive use; perceptible information; tolerance for error; low physical effort; and size and space for approach and use. And accessible does not mean less play. Situational engagement has made for a more equitable design, treating BLV individuals not as users requiring separate accommodations but rather as participants in the same activities.

Universal Design: Support, Challenge, and Refinement

The results support and challenge the principles of Universal Design (UD). On the one hand, the prototype handled perceptible information by splitting information over several input channels. The two block shapes are easy to tell apart by touch alone, and the audio cues in the gameplay and instructions are tailored to convey meaning as much as possible. The "click" would give Becky the extra assurance she said William needed in order to begin playing. They also ensure play is not sight-dependent, an example of UD's stated goal to create products that everyone can use directly.

Finally, there is the principle of equitable use: there is no separate BLV version. It consists of the same blocks, the same system and the same rules as the sighted version. It challenges other parallel products (for example, board games with Braille versions) to establish an inclusive policy from their beginning.

However, the research showed that Universal Design "one-size-fits-all" approach doesn't fit all people, and the needs of the participants can often conflict. Ashley preferred minimalism. Jeff wanted tactile and audio feedback. Becky described tactile feedback, but placed a greater emphasis on safety and durability. Because there was no single solution that would work for all, this is consistent with critiques of UD, specifically that it runs the risk of oversimplifying users by assuming that users share commonalities and have similar needs (Hamraie, 2017).

As well as “equitable use”, Universal Design includes a philosophy of “neutral” design, having no positive or negative impact on any group of users. This would sometimes cause a conflict between usable and accessible. A “safe” accessible design would cause no stimulation whatsoever by using flat surfaces, no textures or patterns for example, and generic shapes. Whilst these present difficulties of reading and interpretation for tactile differentiation users, the strength of design decisions taken in this research reduces these effects. It was important for the “click” sound to have a loudness that was heard and felt, and ultimately be “pleasurable” in the sense that it would reassure William. Examples of similar sound and/or feel branding include the well known clicks of the Bic pen and Nintendo Switch which used the click for marketing purposes. In many cases, instead of reducing feedback, haptics and sound can make the feedback simultaneously more convincing, more informative, and more trustworthy, albeit still needing to be clearer.

In this sense, universal design principles are meant to be coupled with being bold and user centred. Flexibility in use includes a range of individual preference and abilities and does not exclude a range of specificity. Despite the emphasis on multisensory information acquisition, the results showed that UD can trade-off salient sensory stimuli for safety and generalization for BLV users. Therefore, product design in UD does not have to be confined to a neutral point but can also take the user experience into account.

Design Justice: Redistributing Power in Co-Design

The project shows and refers to the principle of Design Justice that “those most affected should lead the process” (Costanza-Chock, 2020). Engaging and empowering BLV individuals as co-designers, rather than simply using them as participants to test and validate, led the design process in a fundamental direction not possible when designing for rather than with.

A case in point: a participant once said during an early interview that “imagination is not solely visual”, implicitly correcting my use of the verb “imagine”. Reflexive analysis of this incident revealed an invisible micro-aggression, however unintentional, by centring what happened to the sighted. It led me to further reflexivity, on the role of visual metaphors in design discourse, the need to de-centre visual embodiments, and the realisation that the barrier to participatory inclusive design was not the sightedness of participants but the ignorance of the researcher.

There must be some degree of tension intrinsic in this project, for I was the sighted designer who made the final choices about form, material and interaction, despite the participatory approach to the work as a whole. Costanza-Chock (2020) would ask whether the community owned the outcomes (and I would say that they shaped them deeply but did not own them in the fullest sense): the blocks, the resistor system, the colour choices, all of that was emergent in response to participant input, but the final outcome was ultimately my technical and aesthetic judgement. This is the irreducible limitation of any practice-based research conducted by a sighted designer in a BLV context, and subsequent iterations of this work should consider models where the BLV participants have greater agency over the final prototype.

Perhaps if more time were spent on the aesthetics or if the interlocking mechanism was simply a functional addition, then the user's experience would not have been affected that drastically. However, with user feedback placing more emphasis on the "click" and altering the experience from merely functional to enjoyable, I adjusted the click to provide a more pleasurable experience. Tactile and sound feedback are not simply secondary, but central, to the user's experience.

For example, in the iterative prototyping process for the 3D printer, the educators and users from BLENNZ also considered the early resin 3D printer outputs to be problematic for three reasons (sharp edges, tipping towers and potentially toxic). The iteration to FDM printing and the baseplate board design were both directly influenced by this feedback. It illustrates participants' lived expertise in identifying problems that were not anticipated by myself, contrasting with critiques made by Design Justice of customary design processes that impose solutions without community input.

This process of revealing the role of language and positionally as a sighted designer exemplifies how the very act of researching disability produces power imbalances. This requires a willingness to relinquish decision-making power, to listen, and to confront participants' ideas when they conflict with those of the facilitators. This reflexivity is important to ethical co-design, in that it prevents participatory processes from merely extracting knowledge from marginalised communities and instead favours redistributing design agency.

Overall, the project shows that blind-led co-design can create better and more ethical designs, disrupting the customary graphic and product design process whereby designers receive briefs from clients and turn them into products without challenging the status quo about what is acceptable or expected from those being designed for. The transition from designing for disabled people to designing with them, also reinforced the principle that inclusive design is for everyone, not just people with permanent disabilities, and that the best solutions to accessibility barriers come from communities themselves.

Multisensory Theory: New Insights and Cross-Modal Correspondences

Literature on multisensory interaction has stated that the brain also has the ability of replacing the information from one modality with the information from another modality (Cho, 2021), such as replacing visual information with auditory information. This suggests that BLV individuals may be able to structure a spatial and semantic understanding of the environment by using other modalities. The present study supports this hypothesis and further extends it by showing that BLV individuals use different perceptual modalities to structure their experience in the environment with cross-modal correspondences.

Cross-modal correspondence is the propensity of the brain to associate information across sensory modalities in non-arbitrary ways. For example, higher musical pitches are associated with the dimension of physical height, while lower musical pitches are associated with the dimension of lowness. This structure is not arbitrary but, rather, it reflects the structure of sensory information processing in the brain. In this way, the musical block game also reflects the principle of the height to pitch relation. This means that even without vision, users have internalised that vertical height corresponds to pitch, and this has been validated by the data showing that users use sound to navigate the environment.

Jeff's observation that sound tells him where he is (Jeff Boudwin, personal communication, 2025), echoed by Jowairya's use of her cane to map spatial boundaries (Jowairya Soliman, personal communication, 2025), further support the notion that, for BLV people, auditory feedback is one of the modalities providing spatial knowledge and orientation. Sound is navigation and meaning simultaneously, further reinforcing the idea of auditory feedback's role in non-visual knowledge construction. The finding adds to the literature on multisensory design: it shows that multisensory design is not merely a crutch but a mode of knowing. The blind do not merely lack access to vision; they construct meaning differently, in more represented and sensory ways, and in ways that work against the visual hierarchy of graphic design systems.

The interlocking "click" of the blocks is an integration of senses: the sound and feeling verify an action. Indeed, it evokes a sense of completion and certainty. The comparison captures the redundancy and synergy of the multisensory feedback: the click's sound and feeling together both assure us the action was received and provide more information and richness than either modality alone. Becky says the click "gives [William] confidence", which shows that the multisensory feedback can also have emotional and psychological effects improving the sense of agency and competence.

In addition to colours, roughness is associated with "anger" and smoothness with "calm" in the users experience. Although subjective, these associations are culturally relevant and could potentially be harnessed by product designers. This association is similar to other weak synesthetic associations between sensory modalities: the association of texture and emotion, or pitch and brightness is consistently reported in non-synesthetes (Cho, 2021). For designers, this could mean that purposefully matching texture to a particular sound or emotion improves the expressive potential of a multisensory communication system.

The notion of tactile hierarchy, auditory hierarchy, and haptics of experience challenges standard approaches to experience design that reduce design to visual design and turn tactile and auditory modes into secondary and compensatory modes of engagement. The challenge is for designers to reshape design approaches to take account of the full range of the human sensory experience in order to rethink how communication, hierarchy, and interaction are achieved across visual, auditory, and tactile modalities.

The principles of integration over substitution, structured simplicity and social equity discovered in the thematic analysis form the theoretical and empirical basis of the design decisions made in the next chapter. The designs in Sound Stack are each based around one of the three principles. A shift from analysis to making is not a break, but instead the most primary, generative form of knowing produced by research.

Design Development and Gameplay

This chapter is about the development of this practical outcome from early prototyping explorations through to the fully realised multisensory game-play system. Detailing the iterative refinements of the block structure and the transition to the embedded electronic system, it documents how the gameplay modes were developed through a combination of technical affordances and constraints and participant-informed design decisions.

The project shows that principles of inclusion are not add-ons but are necessarily entailed by the material, structural, and interactional logic of the system.

Prototype Iteration and Material Development

The block system was developed through exploration, experimentation and practice-based research, with prototypes evolving through numerous cycles of making, testing and refinement. Explorations of form, material and interaction in the first prototypes already revealed limits to tactile clarity and structural stability.

The block shapes were originally focused on having variety rather than functional implementation, as variations in angles or proportions could not be differentiated by players with their sense of touch and were overly difficult to tell apart in practice. It was standardised into an osteomorphic shape drawing from architectural references to create recognizability, consistency, and ease of use. This aligns with tactile design principles of clarity and perceptual legibility through simplification.

Further testing with materials found resin prototypes to be brittle and unsuitable for handling by younger users. The ability to print strong, high contrasting, and non-toxic parts with FDM 3D printers increased ease of use and accessibility of the tools' components.

Tactile markers have also evolved, becoming less cognitively demanding and surfaced with simple edges that offer orientation without excess detail to interfere with the tactile graphics they accompany. Spacing and composition of graphics are also key factors.

Through these iterations, the blocks evolved to communicate their function through form, texture, and interaction rather than visual detail (See Figure 4).

Structural System: From Magnets to Electrical Interlocking

Switching from a magnet-based connector to an electrically conductive interlocking system was one of the project's major technical challenges to overcome.

The magnets used in the earliest prototypes to hold both components in place also provided the tactile feel of a "snap" when the latch was locked, though this was of less importance with the electronic system. However, the resistors in blocks needed stable electrical connections, making magnets unsuitable for use, as they would disturb electrical signals and the structural integrity of blocks.

As a result, the design was changed to have a mechanical snap-fit system that simultaneously provides structural stability, tactile and auditory feedback, and reliable electrical connectivity (See Figure 5).

As a result, the blocks were designed to be slick and snap together, with the same points that touch externally also touching internally.

Figure 4 — Prototype iteration sequence

Resin and shape prototype experimentations.

Osteomorphic shape

Brittle Resin

Early Resin and Ink experimentation

FDM Interlocking exploration

Refined prototype, with indicators

Pogo pin connectors were included in each block to route electrical signals through the stacked blocks. Pogo pins are spring-loaded pins which stack through the blocks and bridge the base plates, creating a stack with an unbroken electrical connection between blocks.

This system meets several design requirements by providing a pleasantly tactile satisfying “click”. While simultaneously establishing an electrical connection for signal transmission. This design enables strong physical interaction without sacrificing durability, and supports modular expansion through the addition of further baseplates.

The shift to pogo pins is an example of practice-based research in which decisions are often based on design constraints and opportunities that emerge through the act of making.

Embedded Logic: Resistor-Based Interaction System

The introduction of the resistor-based system fundamentally changed the game. The touch-based interaction mechanism was embedded, rather than requiring scanning an external surface.

Each stack block contains a resistor; the note block completes the circuit. Adding blocks alters the resistance of the stack, allowing the game’s height sensing to detect the current height of the tower through analogue input.

The strengths of this solution lie in that interaction in this way becomes combined naturally with the physical system, avoiding the need for additional scanning devices that the user might accidentally move or topple over, and once the hand user has connected the blocks, the rest of the feedback is immediate, reducing cognitive and physical burden on the user.

The baseplate serves as the interface for reading the resistance values and converting them into notes, as well as recognising encountered towers in a specified order; multiple plates can be chained to form longer phrases.

Its principle of stacking allows the physical layout of the object to control the sound of the object. As a language, it allows direct, intuitive input that is contained within its medium.

In other words, it greatly increases accessibility, requiring no aim, scan or alignment with an external device, it may be interacted with entirely through touch and construction, allowing free independent interaction.

Translating Graphic Design into multisensory Systems

In developing the gameplay system, I based the design's foundations around a philosophy of graphic design, translating concepts such as typography, layout, and hierarchy into haptic and temporal parameters.

Tactile Graphics and Non-Visual Typography

In developing the graphic design philosophy of Sound Stack, I drew on the principle that visual design rules cannot be directly mapped to touch. As Rong et al. (2025) note, tactile graphics require their own logic of sensory perception and embodiment, distinct from visual hierarchy.

It explores line weight as thickness and relief, and typographic contrast as texture, form and space. Each typographic gesture is pushed to the extreme as a tactile representation of the subtle variations that exist in typography.

Hierarchy is communicated through differences in block height, texture and edge differentiation markers, and snap feedback.

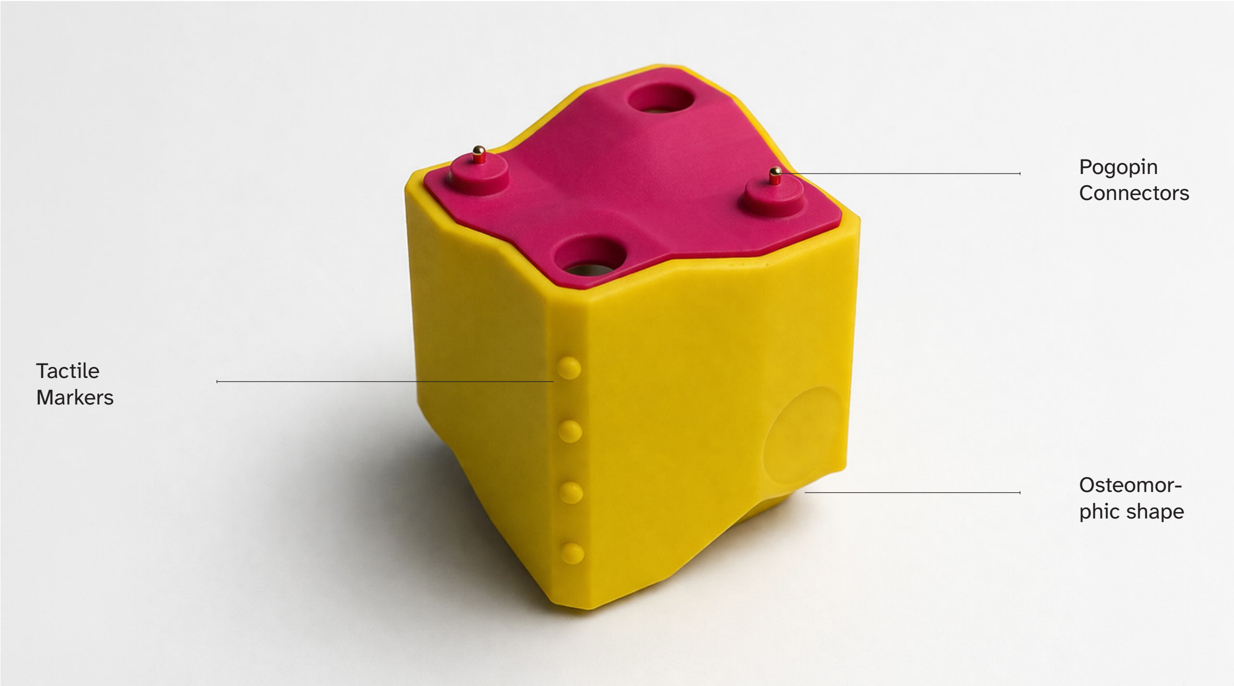
Audio provides a third layer of time, which can break information into small, discrete pieces by providing short, structured voice instructions or auditory cues, thus conforming to research on auditory processing and cognitive load.

Layout as Physical and Sequential Structure

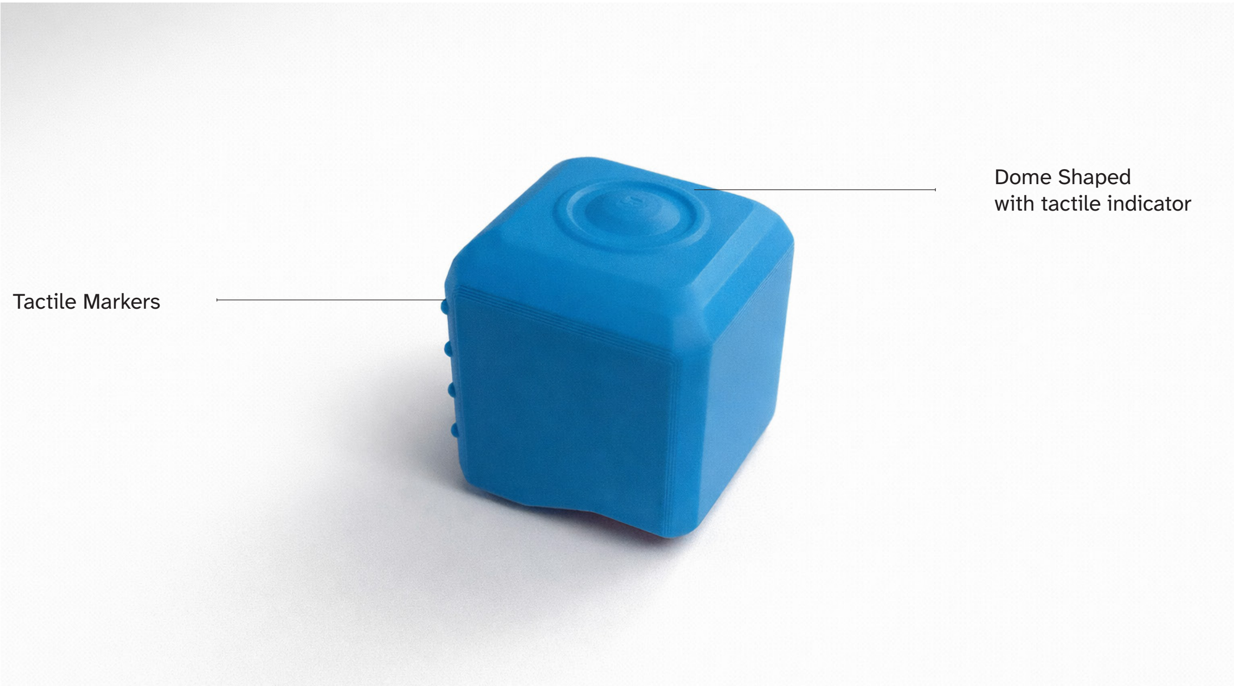
Layout is no longer simply a visual arrangement but rather a spatial and temporal experience.

The baseplate system can be likened to a raised tactile map where the towers denote each position in the sequence, and a player uses their sense of touch to explore this system in whole, rather than only a visual map.

Figure 5 — Block anatomy



Stack Block with pogo pin connectors and tactile markers.



Note Block with dome tactile marker.

Users create and interpret sequences through three simultaneous physical acts: building upward through vertical stacking, arranging laterally through horizontal positioning, and listening to sequential playback in the order the towers were placed. Layout is thereby transformed into a represented process of making meaning together over time.

Hierarchy Through Haptic and Sonic Feedback

Visual hierarchy is mediated through haptic feedback and sound.

As the height of the stack can already affect the pitch, the interlocking provides tactile feedback, linking the shape of the instrument with the pitch produced.

Hierarchy is reinforced through three converging signals: taller stacks produce a higher pitch, towers are played back in the sequence in which they were constructed, and audio feedback confirms each successful interaction. Together these allow a person to perceive structure entirely through touch and hearing, without any visual reference.

The Role of the Designer in multisensory Systems

Here the graphic designer is not only a visual designer, but also a designer of interaction, sound, and material behaviour.

Design decisions extend into the tactile specification of form, texture and material resistance; the interaction logic of stacking and sequencing; and the audio mapping of pitch, timing and feedback. This requires a cross-disciplinary approach in which prototyping and testing are essential to ensure that each sensory channel provides perceptual clarity and usability in combination with the others.

Gameplay Development

The gameplay was generated from interacting with the system, with the core mechanic being stacking blocks into towers, whose height determines a note with which the player can create music.

This creates a system in which sound occurs through physical contact, structure defines sequence, and feedback reinforces understanding. The gameplay is fully multisensory, incorporating tactile building, audio output and three-dimensional spatial reasoning as co-equal elements of play.

Gameplay Modes

The gameplay modes of Sound Stack are not separate modalities, but different ways of engaging with the same multisensory system. There are no rules that differ across the modes — rather, each mode shapes how the player interacts with touch, sound and sequence over time. Each mode orders these three inputs differently, creating a consistent interaction model that caters for varying levels of familiarity, confidence and challenge.

Three primary modes were designed, each corresponding to a distinct phase of player engagement: orient (Instruction/Introduction Mode), explore (Free Play), and challenge (Memory Echo) (See Figure 6).

Card Markers and Mode Symbols

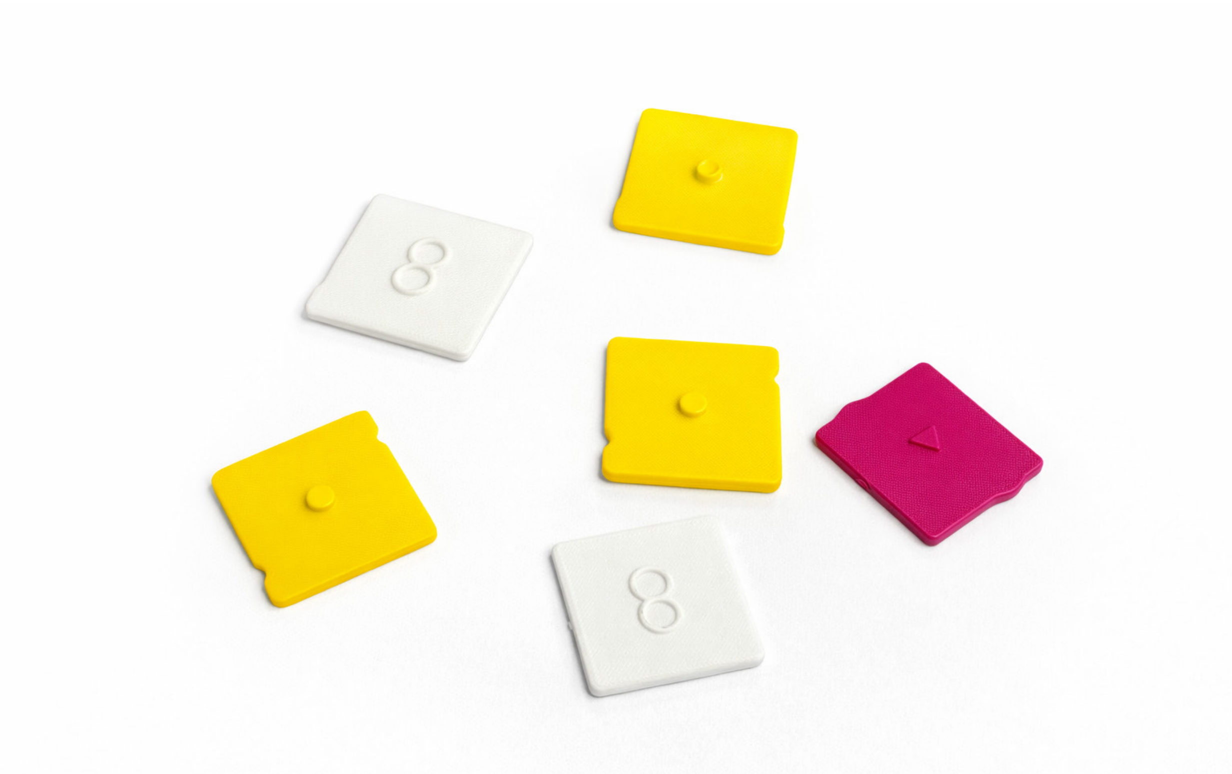
On the face of each Sound Stack audio card has different physical characteristic that allows the player to identify the card by touch. The three mode cards are identified by three different shapes (see Figure 6).

The concept of the blocks' multimodal design is extended to the card interface, ensuring that each point of interaction within the game relies on touch, thereby operationalising the Universal Design principle of perceptible information through multiple channels (Center for Universal Design, 1997). The markers provide tactile redundancy in addition to the audio cue associated with each card. Although not participant tested, the markers were created in response to participant feedback that the key messaging should prioritise clarity, simplicity and non-visual navigation cues throughout the system.

Figure 6 — Gameplay modes overview and Card markers diagram

Symbol	Meaning
	Introduction Card: Instruction Mode introduces the system.
	Save Card: The save card allows players to store a sequence.
	Replay Card: The replay card plays back what has been created.
	Reset Card: The reset card clears the system and allows players to start again.
	Memory Echo: The system plays a sequence of notes. Players recreate it by stacking blocks to match the melody, reinforcing auditory memory and pattern recognition.
	Free Play: Open composition. Players explore stacking blocks in any order to create unique melodies and spatial sculptures, supporting creativity and self-expression.
	Co-play(conceptual): A shared, collaborative form of interaction, where multiple players contribute to a single musical sequence. Instead of one player constructing all four towers, each participant is responsible for building one tower, passing the baseplate between players as the sequence develops.

Figure 7 — Gameplay cards



Audio card mode markers: Memory Echo (wave), Free Play (triangle), Co-play (diamond).

Instruction Mode (Audio Onboarding)

Instruction Mode is delivered by an audio card, which walks the player through the game without written instructions or diagrams. The audio guide familiarises the player with the game's physical and sensory environment and basic mechanics before any actions or real-time decisions take place, giving the player an opportunity to learn the game in advance.

The player can now explore the baseplate by feeling, noticing where the four towers should be placed. The player knows which block is which, due to the different shapes of the blocks: the dome of the note block is much more obvious than the flat side of the other blocks. The relationship between the height and the pitch is introduced to the player. This mode can reduce the cognitive load of the game because the player does not have to play against a timer. The tutorial allows and enables both sighted and blind players to peacefully learn the game.

This replaces the rulebook experience, and better addresses player feedback from Jeff Boudwin who suggested both voice directions to teach players and allowing the players to learn the game as they go with audio cards they scan, rather than forcing players to read printed cards (Jeff Boudwin, personal communication, 2025).

Free Play (Exploratory Mode)

Under Free Play, the player is free to stack towers of any height in any of the four placements on the baseplate, with each tower producing a single note through the sound system, allowing the player's selected order to dictate the order in which the music is played.

The support for saving, loading and replaying sequences eases writing longer compositions over several sessions. The mode allows users to enter an open-ended form of expression, setting the system to be a musical instrument free from rules where players can explore the relationship between touch and sound entirely on their own terms.

Free Play also highlighted issues of agency and directly connected to the participant feedback that stressed open-ended exploration and personal meaning making. As Karen Plimmer elaborated, social and expressive play is particularly useful for BLV children, as they are often excluded from mainstream creative activities (K. Plimmer, personal communication, 2025), so this mode is designed to allow full participation in such activities.

Memory Echo (Recall and Pattern Recognition)

Memory Echo is a listening and recall game in which the player has to recreate a sequence of notes. The player creates towers of differing heights to recreate the sequence, receiving an audio acknowledgment when it is successfully completed. If the player fails to correctly reproduce the sequence, the game will replay the sequence of notes, promoting learning through repetition rather than penalisation.

Because relative pitch rather than notation is used, the mode can be used by musicians without formal musical training. It is based on the principle of repetition and patterning as in Braille music notation (World Blind Union, 1997). This was confirmed in my study by musician Karen Plimmer who holds a Bachelor of Music and is a postgraduate music student. In contrast, Braille musicians must memorise larger amounts of music before a performance, as only one line of Braille music can be read at a time. For Braille readers, repetition is not a pedagogical choice, but a structural necessity (Karen Plimmer, personal communication, 2025).

This mode further draws on the relationship between the output of sound and the tactile performance of the object. The relationship between input and output allows the player to internalise pitch differences. This mode also has a difficulty curve that leads the player from orientation, through exploration, to challenge.

Co-Play Mode (Proposed Mode)

This shared experience of play was one of the themes run through many of the interviews with participants when talking about social inclusion, where participants including Debbie Kokay and Karen Plimmer highlighted how BLV people are often separated from shared play rather than being co-located with sighted peers (Debbie Kokay, personal communication, 2025; Karen Plimmer, personal communication, 2025). This could be in the shape of one player taking turns at each of the four tower locations, with their individual notes then composed into the music that the system plays back to them. The shift from one-to-one communication to collective authorship entails different interests and positions and investments in different types of knowledge.

The coding architecture never fully made it into the final prototype. Single-player sequential input may be simple, but detecting players' input actions in a shared session was too timing-complex for the Arduino Coding. Development focused on Instruction Mode, Free Play and Memory Echo, three types of interaction considered stable and testable enough to work on. Collaborative play is a further avenue for development, extending the Sound Stack beyond accessibility for individuals to truly shared experience. This is in line with the principles of design justice that stress collective participation rather than accommodation (Costanza-Chock, 2020) and with recent research highlighting social inclusion as an underexplored dimension of accessible game design (Hassan & Baltzar, 2022).

Synthesis: From System to Experience

The end result is a shift from designing single components to designing an integrated multisensory system.

In doing so, the project addresses the research questions by showing how multisensory design methods can be integrated within the graphic design process to produce meaningful, inclusive design outcomes.

Conclusion

The project intended to explore what aspects of inclusive design could support an accessible design for BLV and to see how multisensory design might be taken into account. I facilitated a series of interviews with eight BLV users and two BLENNZ practitioners, which led to the development of Sound Stack, a musical block game which encodes the identity of the object through use of touch, sound and structure.

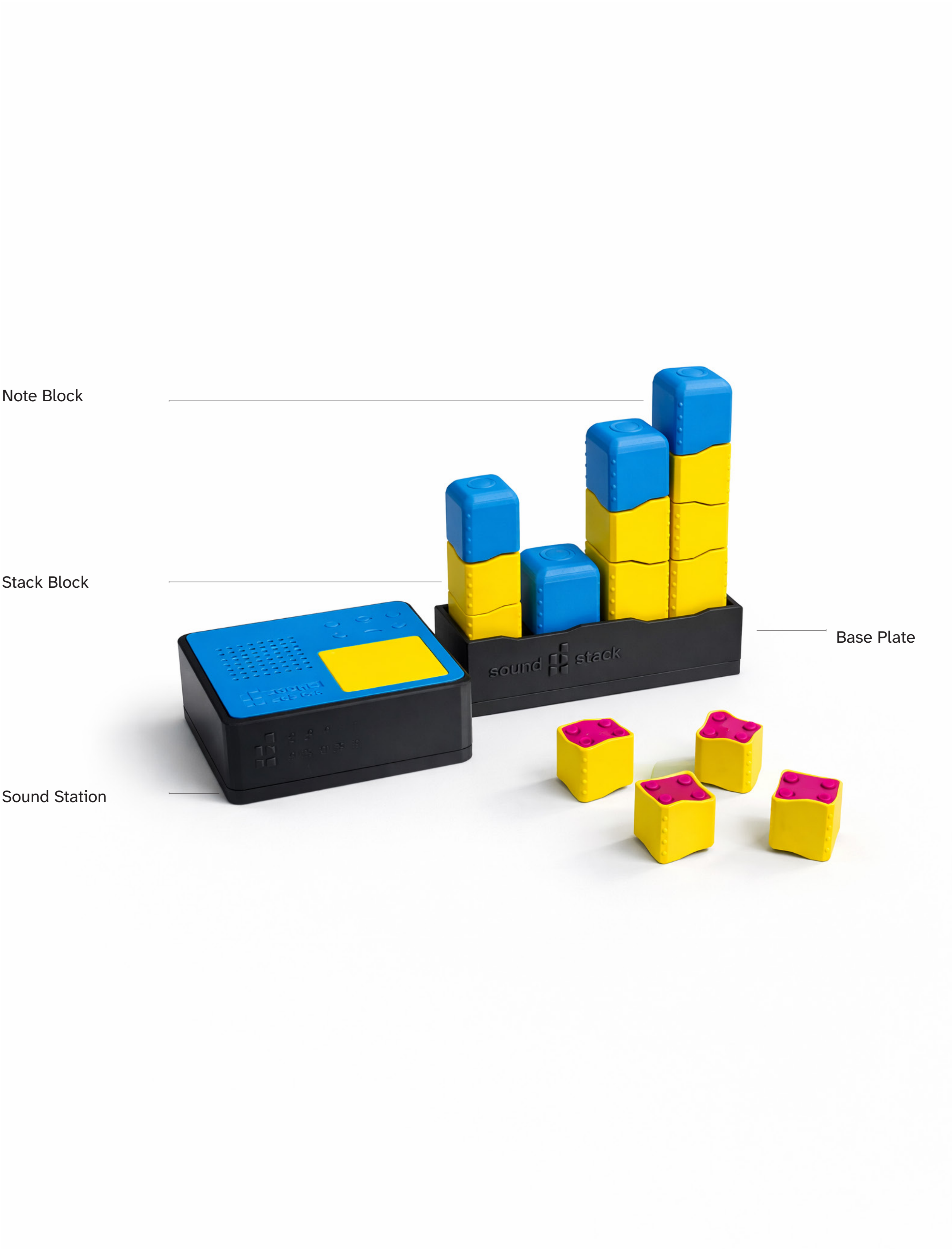
For the first research question, the research identified five principles of inclusive design that may assist in making design more accessible to BLV users through a literature review and co-design with participants: multisensory integration as primary language, simplicity without impoverishment, tactile and auditory redundancy, social equity of participation, and customisation to accommodate intersectional difference. For the second research question, the research identified that embedding touch, sound and physical structure as co-equal channels from the outset of the design process and as intrinsic to output rather than post-hoc add-ons produced a more fundamentally inclusive and engaging design output than one that used only visual and textual channels. Sound Stack is the material evidence of both answers.

I found that multisensory integration is used as a full design language by BLV designers who create multiple associations across their various tactile, auditory and spatial experiences. Sighted designers, on the other hand, are less likely to consider or incorporate such associations in their design even despite the fact that multisensory integration is possible for them. Furthermore, there was agreement that the prototype would need to move from a graphically coded scanner-based architecture to a physically intuitive embedded block architecture.

The study also suggests the need for accessibility and richness need not be contradictory. Simplicity of form does not correlate with poverty of experience, and the game shows how tactile and auditory complexity can produce rich play without requiring visual literacy. Limitations of this work include the lack of a controlled usability study. Future work should include a larger playtest study with more diverse BLV participants including children, BLV participants with other disabilities, and participants who are not BLV. Additional iterations could also include features such as adjustable musical scales and vibrotactile feedback, or multiplayer modes where participants must work together to form longer phrases across baseplates.

Thus this project has not only produced a practice-based prototype and a set of co-design principles for graphic designers working with BLV communities, but has reframed inclusive design in graphic design as a pro-active creative practice that delivers better, more meaningful design for everyone.

Figure 8 — Final System



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