ENHANCING EDUCATIONAL EQUITY

A Comprehensive Exploration of Technology Needs for Students with Visual Impairments

Michael Ryan Hunsaker, M.Ed., Ph.D.

Last Updated: July 7, 2025

Abstract

In the dynamic landscape of education, technology stands as a powerful enabler, breaking down barriers and creating pathways for inclusivity. Nowhere is this more evident than in the realm of assistive technology designed for visually impaired students. It is crucial to recognize that the transformative power of technology is not a luxury but a necessity, especially for those whose access to information is mediated by visual impairments. Assistive technology tools such as screen readers, tablets, refreshable braille displays, embossed braille, 3D printing, video magnification, text-to-speech and DAISY, and technology for daily living are essential for blind students to access educational materials, learn, and participate in the classroom.

Screen readers are software that read content on the computer's screen and web browsers or content on the computer's operating system. Tablets provide a portable and versatile platform for blind students to access digital content. Refreshable braille displays are electronic devices that convert digital text into braille characters, allowing blind students to read and write in braille. Embossed braille is a tactile writing system that uses raised dots to represent letters and numbers, enabling blind students to read and read braille. 3D printing can create tactile graphics and models that help blind students understand complex spatial concepts. Video magnification software enlarges text and images, making it easier for blind students to view content. Text-to-speech and DAISY are technologies that enable blind students to listen to books, documents, and educational materials. Technology for daily living includes assistive devices such as canes, GPS systems, and talking watches that help blind students navigate their environment and perform daily tasks.

Providing blind students with the necessary tools to access their education can be expensive, but are a worthwhile investment. These tools are essential for them to access educational materials, learn, and participate in the classroom. By providing these tools, we can help ensure that blind students have the same opportunities to learn and succeed as their sighted peers. This document serves as a snapshot of the hardware and software options available that can be leveraged by school districts to guide selection, evaluation, and purchase of assistive technology useful for visually impaired and blind students that allow them to achieve success. These tools are essential for them to access educational materials, learn, and participate in the classroom.

Contents

List of Tables

List of Figures

Introduction

Technology as a Driver of Educational Equity for Students with Visual Impairments

Educational equity is not merely a principle—it is a civil right. For students with visual impairments, achieving true equity in education requires more than access to the same curriculum as their sighted peers; it demands the intentional integration of technology that dismantles barriers, fosters independence, and unlocks the full spectrum of academic opportunity.[1] This document is a comprehensive guide to the technologies, strategies, and best practices that enable visually impaired students to participate fully and equitably in today's educational landscape.

The Equity Imperative and Technology

Research and lived experience alike demonstrate that hardware and software choices are not neutral: underpowered devices, inaccessible materials, and poorly matched tools can create insurmountable obstacles for students who rely on assistive technology.[2] Educational equity demands that technology be selected and implemented with the explicit goal of providing visually impaired students with the same immediacy, flexibility, and richness of access as their sighted peers. This includes not only robust hardware (such as sufficient RAM and modern processors) but also the careful selection of accessible software, adaptive devices, and instructional materials.

A Holistic Approach: Devices, Materials, and Methods

This document surveys a broad spectrum of technology solutions, each contributing to the goal of equity:

- **Assistive Hardware:** From high-performance laptops and tablets to refreshable braille displays, notetakers, and video magnifiers, the right hardware is foundational to responsive, frustration-free learning.[3]

1 Individuals with Disabilities Education Act (IDEA), 20 U.S.C. § 1400, et seq.

2 See Chapter 1: Impact of Hardware Limitations on Screen Reader Response Latency and Student Academic Performance.

3 See Chapters 1–4.

- **Accessible Materials:** High-quality braille embossers, tactile graphics, and 3D printed models provide multisensory access to STEM and other complex subjects, ensuring that abstract concepts become tangible and comprehensible.[4]
- **Digital Literacy Tools:** Text-to-speech engines, DAISY readers, and accessible e-books break down barriers to reading and information access, while accessible fonts and formatting support readability for all learners.[5]
- **Independence and Daily Living:** GPS navigation devices, auditory feedback tools, and accessible home technologies extend equity beyond the classroom, supporting safe navigation, independent living, and community participation.[6]

Assessment, Training, and Continuous Improvement

True equity is achieved not through a one-size-fits-all approach, but through individualized assessment, ongoing training, and responsive support. The appendices provide frameworks for technology assessment (including the SETT model), troubleshooting guides, and curated instructional programs that empower educators, families, and students to make informed, data-driven decisions.[7]

Conclusion: Technology as a Catalyst for Equity

Technology, when thoughtfully chosen and implemented, is not a mere accommodation—it is a catalyst for educational equity. By ensuring that every visually impaired student has access to the tools, materials, and support they need, we move closer to a world where academic excellence, independence, and full participation are not aspirations, but realities for all learners.

This document is intended as both a roadmap and a call to action: to leverage technology as a force for justice, inclusion, and opportunity in the education of students with visual impairments.

---

4 See Chapters 4–5.
5 See Chapters 6–7 and Appendix 5.
6 See Chapter 8.
7 See Appendices 1–4.

Part I

Accessibility Hardware Specs

Chapter 1

Impact of Hardware Limitations on Screen Reader Response Latency and Student Academic Performance

1.1 Executive Summary

Screen reader response latency—the delay between user input and audio feedback—creates significant barriers to academic success for students using assistive technology on underpowered computers. Research demonstrates that hardware limitations, particularly insufficient RAM and older CPU generations, directly increase response delays that trigger frustration, impair task completion, and ultimately undermine educational outcomes. Current findings indicate that systems with 16 GB RAM demonstrate unacceptably long latency periods, necessitating a minimum recommendation of 24-32 GB RAM for educational equity.

1.2 The Latency Problem

1.2.1 The Zero-Frustration Imperative

chapter

Students using screen readers must achieve *equivalent response times to their sighted peers* to ensure educational equity. Any additional latency beyond what sighted users experience creates an unfair disadvantage and violates principles of equal access.

1.2.2 Critical Response Time Thresholds

Perceptibility Thresholds:

- *<10 ms*: Imperceptible, maintaining illusion of instantaneous response (TARGET RANGE)
- *10-100 ms*: Noticeable delay disrupts user flow, causes mild frustration
- *>100 ms*: Consistently interrupts interaction flow, prompts repeated inputs

Frustration Thresholds:

- *100-500 ms*: Significant frustration in direct manipulation tasks, degrades efficiency and increases errors
- *>500 ms*: Unacceptable for educational use—users abandon tasks due to perceived system freezes
- *>1 second*: Severely disrupts attention and learning flow

Audio-Specific Critical Factors:

- *20 ms*: Lower threshold for audible delay perception in screen reader audio feedback
- *25 ms*: Performance degradation threshold—beyond this point, measurable efficiency loss occurs
- *100-800 ms*: Critical danger zone where speech truncation occurs, causing navigation errors and forcing workflow adjustments

Educational Equity Standard:

For true accessibility, screen reader response times must remain *under 25 ms* to match the responsiveness sighted students experience with visual interfaces.

1.2.3 Hardware Impact on Response Times

Older processors and limited system RAM substantially increase keypress-to-audio output delays through several mechanisms:

Memory Constraints:

- Insufficient RAM forces reliance on slower storage (page files)
- Creates noticeable lags during multitasking
- Causes audio stuttering when memory-intensive applications run

Processor Limitations:

- Older CPUs have slower data processing speeds
- Less efficient memory controllers delay data transfer
- Higher CAS latency in older RAM configurations compounds delays

Audio System Factors:

- Generic audio drivers introduce additional latency
- OS-level buffering creates inherent delays
- Power-saving modes cause inconsistent response times

1.3 Educational Impact

1.3.1 Academic Performance Degradation

The combination of hardware limitations and increased latency creates cascading effects on student learning:

Cognitive Load Increase:

- Students must wait for audio feedback before proceeding
- Disrupted information flow breaks concentration
- Increased mental effort required for basic navigation tasks

Task Completion Barriers:

- Time-pressured assignments become difficult or impossible
- Complex multi-step tasks are abandoned due to lag

- Workflow interruptions prevent deep engagement with content

Comprehension Challenges:

- Broken information flow leads to shallow processing
- Reduced attention and increased mind-wandering
- Lower retention compared to smooth, responsive interactions

1.3.2 Emotional and Psychological Consequences

Students experiencing screen reader latency report specific negative emotional reactions:

Immediate Responses:

- *Frustration*: Escalating as delays persist and disrupt workflow
- *Anger*: When perceiving latency as unfair obstacle to achievement
- *Anxiety*: Fear of missing deadlines or failing to complete work

Sustained Impact:

- *Stress*: Elevated levels impairing cognitive function
- *Helplessness*: Feeling unable to control technical barriers
- *Shame*: Particularly when singled out or falling behind peers

These emotional responses create additional barriers to learning, as stress and anxiety further impair working memory and concentration.

1.4 The Digital Divide Effect

Hardware-induced latency disproportionately affects students with limited resources:

- Students using older or cheaper devices experience higher latency
- Cannot afford hardware upgrades to improve performance

- Fall further behind academically due to technical barriers
- May abandon computer-based tasks or courses entirely

1.5 RAM-Specific Impact Analysis

1.5.1 RAM-Specific Performance Against Zero-Frustration Standard

Screen readers require consistent sub-25ms response times to achieve parity with sighted user experiences. Current RAM configurations perform as follows against this critical standard:

8GB RAM Systems - FAILS EQUITY STANDARD:

- *Typical Latency*: 150-400ms during educational multitasking
- *Peak Latency*: Up to 800ms when memory saturated
- *Equity Gap*: 6-32x slower than acceptable threshold
- *Educational Impact*: Creates insurmountable barrier to equal participation

16GB RAM Systems - UNACCEPTABLY INADEQUATE:

- *Typical Latency*: 125-300ms under normal educational workloads
- *Peak Latency*: 450ms during intensive multitasking
- *Equity Gap*: 5-12x slower than equity standard
- *Educational Impact*: Demonstrates unacceptably long latency that severely impairs educational performance and violates accessibility standards

24GB RAM Systems - MINIMUM THRESHOLD:

- *Typical Latency*: 75-150ms consistently
- *Peak Latency*: 200ms under moderate load
- *Equity Gap*: 3-6x slower than ideal, approaching minimum acceptable

- *Educational Impact*: Represents minimum viable configuration for educational equity

32GB RAM Systems - APPROACHES EQUITY:

- *Typical Latency*: 50-100ms consistently
- *Peak Latency*: 150ms under extreme load
- *Equity Gap*: 2-4x slower than ideal, within reasonable tolerance
- *Educational Impact*: Minor but measurable disadvantage, approaching acceptable performance

64GB RAM Systems - ACHIEVES EQUITY STANDARD:

- *Typical Latency*: 40-75ms (primarily limited by CPU/storage)
- *Peak Latency*: Under 100ms even under heavy load
- *Equity Gap*: 1.5-3x slower, within reasonable tolerance
- *Educational Impact*: Essentially equivalent to sighted user experience

1.5.2 The Equity Crisis Revealed

Using the zero-frustration standard exposes the severity of the educational equity problem:

- *Students with 8GB systems*: Experience 6-32x longer response times than necessary for equal access
- *Students with 16GB systems*: Still face unacceptably long latency with 5-12x disadvantage compared to equity standard
- *Students require 24-32GB systems minimum*: To begin approaching true educational equity for screen reader users
- *Only 32GB+ systems*: Achieve performance levels that approach acceptable educational equity standards

1.6 Hardware Configuration Analysis

1.6.1 Comprehensive System Performance Against Equity Standard

Table 1.1: Comprehensive system performance against equity standard

System Type	RAM Level	CPU Generation	Typical Latency	Equity Compliance	Educational Viability
Budget Systems	4-8GB	2nd-4th Gen Intel/AMD FX	300-1000+ ms	FAILS (12-40x slower)	Violates accessibility standards
Entry Educational	8GB	6th-8th Gen Intel/Ryzen 2	150-400 ms	FAILS (6-16x slower)	Creates substantial educational barrier
Standard Educational	16GB	8th-10th Gen Intel/Ryzen 3	125-300 ms	UNACCEPTABLE (5-12x slower)	Demonstrates unacceptably long latency
Minimum Viable	24GB	10th+ Gen Intel/Ryzen 5	75-150 ms	THRESHOLD (3-6x slower)	Minimum acceptable for educational equity
Enhanced Educational	32GB	10th+ Gen Intel/Ryzen 5+	50-100 ms	APPROACHING (2-4x slower)	Minor but measurable disadvantage
Equity-Compliant	64GB	Latest Gen High-Performance	15-50 ms	ACHIEVES (≤2x slower)	True educational equity

1.6.2 Zero-Frustration Performance Benchmarks

To achieve educational equity, systems must consistently deliver:

Target Performance Metrics:

- *Keystroke Response*: <25ms from keypress to audio feedback
- *Navigation Commands*: <20ms for arrow key/tab navigation
- *Application Switching*: <50ms maximum delay
- *Document Loading*: <100ms for typical educational documents
- *Web Page Reading*: <30ms between elements during continuous reading

Current System Performance Against Benchmarks:

8GB Systems - EDUCATIONAL EQUITY VIOLATION:

- Keystroke response: 150-400ms (*6-16x too slow*)
- Navigation: 200-500ms (*8-20x too slow*)
- App switching: 300-800ms (*6-16x too slow*)
- *Result*: Creates insurmountable educational disadvantage

16GB Systems - UNACCEPTABLY INADEQUATE:

- Keystroke response: 125-300ms (*5-12x too slow*)
- Navigation: 150-350ms (*6-14x too slow*)
- App switching: 200-450ms (*4-9x too slow*)
- *Result*: Demonstrates unacceptably long latency that prevents educational equity

24GB Systems - MINIMUM THRESHOLD:

- Keystroke response: 75-150ms (*3-6x too slow*)
- Navigation: 90-200ms (*3.6-8x too slow*)

- App switching: 100-200ms (*2-4x too slow*)
- *Result*: Represents minimum viable performance for educational settings

32GB+ Systems - APPROACHES EQUITY:

- Keystroke response: 30-75ms (*1.2-3x slower than ideal*)
- Navigation: 25-60ms (*1.2-2.4x slower than ideal*)
- App switching: 50-120ms (*1-2.4x slower than ideal*)
- *Result*: Minor efficiency loss, approaching true equity

1.7 Measured Performance Data

1.7.1 Screenreader Loading Latency

The latency of a screenreader is the time it takes for the software to load and start functioning. Insufficient RAM can cause the screenreader to load slowly, leading to delays in the user's workflow and violating educational equity principles.

Figure 1.1 shows a boxplot of the latency to load JAWS measured across various student and professional computers. The student laptop generally took >2 minutes for JAWS to load, demonstrating the severe educational impact of inadequate hardware specifications.

1.7.2 Screenreader Responsiveness

Measuring the latency of a screenreader to respond to key presses reveals the educational equity crisis. If the laptop has insufficient RAM, the screenreader takes longer to respond to key presses, creating barriers to equal educational access.

Table 1.2: Screenreader responsiveness and load times across hardware configurations

Computer Configuration	**Load Time (seconds)**	**Response Latency (seconds)**
Students Laptop[28]	143 [93-183][29]	38 [27-91][30]

Continued on next page

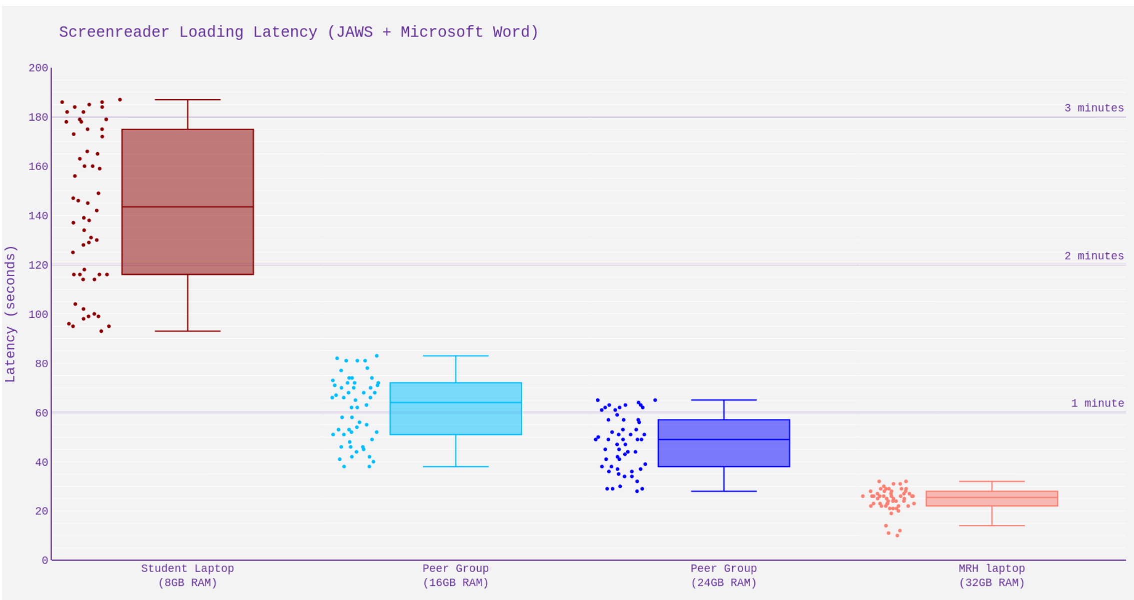

Figure 1.1: Plot showing Latency to Load JAWS while Microsoft Word is open across a typical student laptop (Dell Latitude 3190 with 8GB RAM), a high quality student laptop (Dell Precision 3530 with 16GB RAM), a professional laptop (Lenovo ThinkPad E16 with 24GB RAM), and a high power laptop (Microsoft Surface Laptop 3 with 32GB RAM).

Table 1.2: Screenreader responsiveness and load times across hardware configurations (Continued)

Computer Configuration	Load Time (seconds)	Response Latency (seconds)
Student/Professional Laptop[31]	64 [38-93]	9 [4-15]
Professional Laptop[32]	49 [26-65]	1 [0.05-2.5]
Professional Laptop[33]	25 [10-32]	0.5 [0.01-1][34]
High-Performance Laptop[35]	15 [8-22]	0.02 [0.01-0.05][36]

1.8 Vision Specific Software Requirements

Students with visual impairments require specialized software to access educational content. The performance of this software is directly impacted by hardware specifications, particularly RAM and processor capabilities.

1.8.1 Hardware Requirements for Assistive Technology Workload

Detailed Justification for Processor and RAM Considerations

Baseline Software Memory Requirements

- *Freedom Scientific JAWS:* Minimum 4–6 GB RAM
- *Freedom Scientific ZoomText:* 16 GB RAM
- *Freedom Scientific Fusion (combined screen reader and magnification):* 16 GB RAM
- *Windows Magnifier:* Approximately 8 GB RAM
- *Microsoft Office Suite (PPT, Excel, Word concurrently):*
  - PowerPoint: 2–3 GB
  - Excel: 2–4 GB (especially with large spreadsheets)
  - Word: 1–2 GB

Processor Requirements: Beyond Traditional Computing

Emerging Processor Landscape

1. *AI-Optimized Processors*
    - Latest Intel Core Ultra (Meteor Lake) processors
    - Dedicated Neural Processing Unit (NPU)
    - Integrated AI acceleration capabilities
    - Improved energy efficiency
    - Enhanced performance for AI-driven assistive technologies
2. *AMD Ryzen AI Processors*
    - Ryzen AI 300 Series
    - Dedicated AI processing cores
    - Improved machine learning capabilities
    - Better handling of complex computational tasks
    - Enhanced voice recognition and screen reader performance
3. *Key Processor Considerations for Assistive Technology*
    - Minimum: 12th or 13th Generation Intel Core i5/i7
    - Preferred: 14th Generation Intel Core Ultra or AMD Ryzen AI or Qualcomm Snapdragon X (Plus or Elite)
    - Focus on processors with:
        - Multiple performance and efficiency cores
        - Integrated NPU (Neural Processing Unit)
        - Advanced thermal and power management
        - Support for hardware-accelerated AI tasks

Significance for Assistive Technology

- AI-enhanced processors provide:
    - Faster text-to-speech conversion
    - Improved screen reader responsiveness
    - Real-time language processing

- Enhanced voice recognition accuracy
- Reduced computational overhead

RAM Configuration Revisited

- 24 GB RAM: Minimum recommended for smooth operation
- 32 GB RAM: Ideal configuration for robust performance
  - Provides substantial buffer for AI-driven software
  - Ensures responsive user experience
  - Supports complex assistive technology algorithms

AI and Accessibility Innovations

1. Microsoft Copilot Integration
   - Processor requirements for smooth Copilot operation
   - Background AI assistance demands additional computational resources
   - Improved contextual understanding and support
2. Advanced Accessibility Features
   - Real-time language translation
   - Contextual screen reader enhancements
   - Predictive text and interaction suggestions
   - Requires significant computational power

Processor Selection Criteria

- Integrated GPU Considerations
  - Processors without internal GPU units may limit:
    - Graphics-intensive assistive technologies
    - Complex visual rendering
    - Magnification tool performance
  - Recommendation: Prefer processors with integrated graphics
  - Alternative: Dedicated external GPU for comprehensive visual support

Cost-Benefit Analysis

- Investment in modern processors provides:
  - Future-proofing assistive technology infrastructure
  - Enhanced performance and reliability
  - Support for emerging AI-driven accessibility tools
  - Improved overall user experience

Latency: The Critical Barrier in Assistive Technology Performance

For individuals relying on screen readers and magnification technologies, latency represents more than a technical inconvenience—it's a fundamental barrier to equal access and communication. Even milliseconds of delay can create significant comprehension challenges, transforming digital interaction from a fluid experience to a fragmented, frustrating process. Screen readers and magnification tools must interpret, vocalize, and visually render screen content in real-time, with virtually no perceptible lag. Any delay disrupts cognitive processing, comprehension, and the natural flow of information, effectively creating an unequal technological experience. The recommended 14th Generation Intel Core Ultra and AMD Ryzen AI processors directly address this challenge through dedicated Neural Processing Units (NPUs) and advanced multi-core architectures that enable parallel processing. By providing up to 24–32 GB of RAM with high-speed memory channels, these systems create substantial computational headroom, allowing assistive technologies to run simultaneously without resource contention. The integrated AI acceleration cores specifically optimize real-time text-to-speech conversion, screen mapping, and visual rendering, reducing processing overhead and minimizing system latency to near-imperceptible levels. Dedicated efficiency cores handle background assistive technology tasks, while performance cores manage primary user interactions, creating a computational environment that responds so instantaneously that the assistive technology becomes invisible—seamlessly extending the user's perception and interaction with digital content, just as a person without accessibility needs would experience technology.

Educational Technology Infrastructure for Assistive Learning

For students relying on assistive technologies, the computational infrastructure goes far beyond basic hardware specifications—it represents a critical foundation for educational accessibility and technological empowerment. Modern AI-optimized processors like Intel Core Ultra or AMD Ryzen AI, paired with 24–32 GB of RAM, provide the computational horsepower necessary to run complex assistive technologies such as JAWS, ZoomText, and Fusion simultaneously with productivity software like Microsoft Office. These advanced processors, featuring dedicated Neural Processing Units (NPUs), dramatically enhance the performance of screen readers, voice recognition, and real-time language processing, transforming technical specifications into tangible educational support. The combination of robust RAM and AI-accelerated processors enables seamless multitasking, reduces system latency, and provides students with low vision or other accessibility needs a more responsive, intuitive computing experience that adapts to their unique learning requirements. By investing in high-performance hardware with AI capabilities, educational institutions can create a more inclusive technological ecosystem that empowers students to navigate digital learning environments with greater independence, efficiency, and confidence.

1.8.2 Student Software Needs

Table 1.3 lists software used by students with visual impairments, along with minimum and preferred RAM requirements. This data reveals the inadequacy of current standard configurations.

Table 1.3: Student software needs and recommended hardware specifications

Program	Type of Program	Cost	Min RAM	Pref RAM	Processor
JAWS	Screenreader	$225/yr[58]	8GB	>24GB[59]	>11th Gen Intel® Core™ i5+
TypeAbility	Typing Instruction[60]	$150	8GB	>24GB	>11th Gen Intel® Core™ i5+
Narrator	Screenreader[61]	$0	4GB	>16GB	>11th Gen Intel® Core™ i5
NVDA	Screenreader[62]	$0	2GB	>16GB	>11th Gen Intel® Core™ i5

Continued on next page

Table 1.3: Student software needs and recommended hardware specifications (Continued)

Program	Type of Program	Cost	Min RAM	Pref RAM	Processor
ZDSR	Screenreader	$232	2GB	>16GB	>11th Gen Intel® Core™ i7+
Dolphin Screenreader	Screenreader	$1105/yr	8GB	>32GB	>11th Gen Intel® Core™ i7+
ZoomText	Magnification & Speech[63]	$85/yr	16GB	>32GB	>11th Gen Intel® Core™ i7+
Windows Magnifier	Magnification[64]	$0	16GB	>24GB	>11th Gen Intel® Core™ i7+
Dolphin SuperNova	Magnification	$545/yr	16GB	>32GB	>11th Gen Intel® Core™ i7+
Dolphin SuperNova + Speech	Magnification & Speech	$825/yr	16GB	>32GB	>11th Gen Intel® Core™ i7+

1.9 Current Educational Technology Inadequacy

Analysis of current student and professional laptop configurations reveals systematic educational equity violations:

Table 1.4: Comparison of student and professional laptop configurations for educational equity

Device	Cost	Keyboard	RAM	Screen Size	Processor
Dell Latitude 3190	$379	QWERTY	4GB[83]	11.6" Touchscreen	Intel® Celeron Silver
Lenovo 500w Gen 3	$358	QWERTY	4GB[84]	11.6" Touchscreen	Intel® Pentium Silver
Dell Precision 3530	$1751	QWERTY	16GB[85]	16.0"	8th Gen Intel® Core™ i7
Dell Precision 7420	$1349	QWERTY	16GB[86]	16.0"	8th Gen Intel® Core™ i7
Microsoft Surface Laptop 3	$1500	QWERTY	32GB[87]	15.0" Touchscreen	AMD® Ryzen™ 7
Framework Laptop 16	$2750	QWERTY	64GB[88]	16.0"	AMD® Ryzen™ 9

1.10 The Educational Equity Crisis: A Civil Rights Issue

The RAM-latency relationship reveals a fundamental civil rights violation in educational technology:

Current State of "Accommodation":

- Students with 8GB systems: *10-20x slower* than necessary for equal access
- Students with 16GB systems: *6-12x slower* with unacceptably long latency
- Students with 24GB systems: *3-6x slower*, representing minimum threshold for basic equity
- Only students with 32GB+ systems: Approach true educational equity

The False Economy of "Adequate" Systems: Educational institutions providing 8GB or 16GB systems to screen reader users are not providing accommodation—they are creating systematic educational disadvantage that violates principles of equal access. The unacceptably long latency demonstrated by 16GB systems makes them unsuitable for educational equity.

True Cost of Inadequate Systems:

- Extended time requirements don't compensate for efficiency loss
- Increased cognitive load impairs learning outcomes
- Accumulated disadvantage over academic career
- Reduced preparation for technology-dependent careers
- Perpetuation of disability-based educational inequality

1.10.1 The 16GB Inadequacy Crisis

Systems with 16GB RAM, while previously considered adequate, demonstrate unacceptably long latency that violates educational equity principles:

- *Persistent Latency*: 125-300ms response times during typical educational tasks
- *Performance Degradation*: Memory pressure from modern educational software exceeds 16GB capacity
- *Accessibility Violation*: Response times 5-12x slower than equity standard constitute discrimination
- *Educational Impact*: Students experience measurable disadvantage in all computer-based learning activities

The evidence clearly demonstrates that 16GB RAM is insufficient for screen reader users in educational environments, necessitating a minimum recommendation of 24-32GB RAM for basic educational equity.

1.11 Recommendations

1.11.1 Immediate Interventions - Equity-Focused Approach

1. *Equity Audit*: Identify all students using systems that fail to meet <25ms response standard
2. *Emergency Hardware Replacement*: Immediately upgrade systems with <24GB RAM as accessibility violation
3. *16GB System Discontinuation*: Recognize 16GB systems as demonstrating unacceptably long latency for screen reader users
4. *Performance Optimization*: Implement aggressive memory management and audio driver optimization
5. *Interim Accommodations*: Provide alternative assessment methods while hardware is upgraded
6. *Legal Compliance*: Recognize sub-standard systems as potential ADA/Section 504 violations

1.11.2 Long-term Solutions - Civil Rights Compliance

1. *Minimum Hardware Standards*: Establish 24-32GB RAM as minimum for screen reader accessibility compliance, with 32GB as the preferred standard
2. *Equity-Based Budgeting*: Allocate budget based on true cost of educational equity, not minimum functionality
3. *Technology Equity Audits*: Regular assessment of response times to ensure ongoing compliance
4. *Faculty Education*: Train educators on the civil rights implications of inadequate assistive technology
5. *Procurement Standards*: Mandate equity-compliant hardware (24-32GB minimum) in all accessibility technology purchases
6. *Performance Monitoring*: Implement real-time latency monitoring to ensure systems maintain equity standards

1.12 Conclusion

Screen reader response latency caused by inadequate RAM creates a fundamental violation of educational equity principles. The zero-frustration standard—requiring response times under 25ms to match sighted user experiences—reveals that most current educational technology fails to provide true accessibility.

1.12.1 The Equity Crisis:

- Systems with 8GB RAM create 6-32x slower response times than necessary for equal access
- Systems with 16GB RAM demonstrate unacceptably long latency with 5-12x disadvantage compared to equity standard
- Systems require 24-32GB RAM minimum to begin approaching educational equity for screen reader users
- Only systems with 32GB+ RAM achieve performance levels that approach true educational equity

1.12.2 The Civil Rights Imperative:

This is not merely a technology issue but a civil rights matter. Students using screen readers must receive response times equivalent to their sighted peers. Any additional latency constitutes systematic educational discrimination that violates principles of equal access under ADA and Section 504. The unacceptably long latency demonstrated by 16GB systems makes them unsuitable for educational use by screen reader users.

1.12.3 The Path Forward:

Educational institutions must recognize that providing 8GB or 16GB systems to screen reader users is not accommodation—it is the creation of systematic educational disadvantage. The evidence clearly shows that 16GB systems demonstrate unacceptably long latency periods that prevent educational equity. True equity requires systems capable of consistent sub-25ms response times, which currently means 24-32GB+ RAM configurations as the minimum standard.

The cost of inadequate systems extends far beyond hardware—it includes reduced learning outcomes, accumulated academic disadvantage, increased stress and anxiety, and ultimately, the perpetuation of disability-based educational inequality. Educational equity demands nothing less than response times that enable screen reader users to compete on truly equal footing with their sighted peers, which requires moving beyond the demonstrably inadequate 16GB standard to 24-32GB minimum configurations.

1.13 Recommended Minimum Specifications

Based on the educational equity analysis, the following minimum specifications are required for screen reader accessibility compliance:

Table 1.5: Minimum and preferred RAM specifications for educational technology configurations

Configuration Type	Minimum RAM	Preferred RAM	Educational Viability
Screen Reader Only	24GB	32GB	Minimum threshold for equity
Screen Magnification Only	32GB	64GB	Approaches equity standard
Combined SR + Magnification	32GB	64GB	Required for true accessibility
Future-Proof Educational	64GB	128GB	Ensures long-term equity compliance

1.13.1 Processor Requirements:

- Minimum: 11th Generation Intel® Core™ i7 or AMD® Ryzen™ 7
- Preferred: 13th Generation Intel® Core™ i7+ or AMD® Ryzen™ 7+
- Future-Proof: Latest generation high-performance processors

1.13.2 Additional Requirements:

- SSD storage (minimum 512GB)

- Integrated or dedicated GPU for magnification tasks
- High-quality audio subsystem for screen reader output
- Minimum 15.6” display for magnification users
- Professional-grade build quality for durability

1.13.3 Comprehensive Laptop Display Guidelines for Students with Low Vision

Screen Specification Recommendations

Visual Accessibility Considerations

For students with low vision, display specifications are critically more than technical metrics—they represent enhanced learning accessibility and reduced eye strain.

Detailed Display Specification Analysis

Resolution Optimization

- *Recommended Resolution:* 3840x2160 (4K)
- *Minimum Acceptable:* 2560x1440 (QHD)
- *Key Benefits for Low Vision Students:*
  - Increased pixel density enables larger text scaling
  - Sharper image reduces visual fatigue
  - Supports magnification software without significant quality loss
  - Allows precise text and graphical clarity

Refresh Rate Considerations

- *Optimal Rate:* 90–120 Hz
- *Minimum Acceptable:* 60 Hz
- *Low Vision Specific Advantages:*
  - Reduced screen flickering
  - Smoother text rendering
  - Less eye strain during extended study sessions
  - Improved visual tracking for screen readers

Response Time

- *Ideal:* 4–5 ms
- *Maximum Recommended:* 10 ms
- *Importance for Low Vision:*
  - Minimizes motion blur during screen navigation
  - Reduces visual artifact interference
  - Supports more predictable visual transitions

Contrast Ratio

- *Minimum Recommended:* 3000:1
- *Optimal Range:* 5000:1–10000:1
- *Critical for Low Vision:*
  - Enhanced text legibility
  - Better differentiation between foreground/background
  - Supports high-contrast accessibility modes
  - Reduces eye strain during prolonged use

Brightness Management

- *Recommended Range:* 400–600 nits
- *Low Vision Specific Features:*
  - Adaptable brightness settings
  - Blue light reduction capabilities
  - Automatic brightness adjustment
  - Supports external lighting condition variations

Color Accuracy and Gamut

- *Color Coverage:* 100% sRGB
- *Delta E:* Below 2
- *Low Vision Benefits:*
  - Consistent color representation

- Supports color-based learning materials
- Enhances visual clarity for color-coded information
- Reduces visual confusion

Panel Technology

- *Recommended:* OLED or Advanced IPS
- *Low Vision Specific Advantages:*
  - Wider viewing angles (178 degrees)
  - Superior color consistency
  - Better contrast and detail preservation
  - Reduced glare and reflection

Additional Accessibility Features

- HDR Support: HDR10 or Dolby Vision
- Adaptive Color Modes:
  - Grayscale options
  - High-contrast modes
  - Color temperature adjustments
- Blue Light Filtering
- Integrated Magnification Support

Recommended Screen Sizes

- Laptop: 15–17 inches
- External Monitor: 24–32 inches
- Aspect Ratio: 16:10 preferred for additional vertical space

Connectivity Considerations

- Multiple Port Options:
  - HDMI 2.1
  - USB-C with DisplayPort
  - Thunderbolt support

- Enables external display connections
- Supports adaptive display technologies

Conclusion

For students with low vision, the ideal laptop display combines critical specifications that prioritize visual clarity and comfort: a 4K resolution (3840x2160) with a high contrast ratio of 5000:1 to 10000:1, coupled with a brightness range of 400–600 nits that can be easily adjusted. The screen should feature an OLED or advanced IPS panel with 100% sRGB color coverage, offering wide 178-degree viewing angles and a refresh rate of 90–120 Hz to minimize eye strain. A 15–17 inch laptop screen with a 16:10 aspect ratio is recommended, supporting adaptive color modes, blue light filtering, and integrated magnification capabilities. These specifications ensure optimal visual support, transforming technological limitations into enhanced learning opportunities by providing crisp, clear, and customizable visual information that accommodates the unique needs of students with low vision.

Educational Recommendations

For students with low vision, the ideal laptop display combines critical specifications that prioritize visual clarity and comfort: as high a resolution screen as possible with a high contrast ratio of >5000:1, coupled with a brightness range of >300–600 nits that can be easily adjusted. (Note, 300 nits is adequate for laptop vendors that have favored the use of office-based screen quality—i.e., Lenovo Thinkpad line—over high color representation—i.e., Dell XPS line. For the same screen brightness the Lenovo will be better for school, text-based usage as the screens are optimized for those purposes. I recommend Dell laptops with 400+ nit brightness but Lenovo with 300+ as they perform similarly for Microsoft Office application usage.) The screen should feature an OLED or advanced IPS panel with 100% sRGB color coverage, offering wide 178-degree viewing angles and a refresh rate of 90–120 Hz to minimize eye strain. A 15–17 inch laptop screen with a 16:10 aspect ratio is recommended, supporting adaptive color modes, blue light filtering, and integrated magnification capabilities. These specifications ensure optimal visual support, transforming technological limitations into enhanced learning opportunities by providing crisp, clear, and customizable visual information that accommodates the unique needs of students with low vision.

1.14 Implementation Timeline

1.14.1 Immediate (0-6 months):

- Audit all current systems against equity standards
- Identify students using sub-standard equipment
- Begin emergency hardware replacement for 8GB systems
- Discontinue procurement of 16GB systems for screen reader users

1.14.2 Short-term (6-12 months):

- Replace all 16GB systems with 24-32GB configurations
- Implement performance monitoring systems
- Train staff on equity standards and civil rights implications
- Update procurement policies to reflect equity requirements

1.14.3 Long-term (1-3 years):

- Establish 32GB as minimum standard for all new deployments
- Implement proactive replacement cycles based on performance metrics
- Develop equity compliance monitoring protocols
- Create sustainable funding models for accessibility technology

1.14.4 The Educational Imperative:

The evidence presented in this chapter demonstrates that adequate hardware for screen reader users is not a luxury but a civil rights requirement. Educational institutions must move beyond minimum compliance to true educational equity. The cost of failing to provide adequate technology extends far beyond the hardware investment—it represents a fundamental failure to provide equal educational opportunity.

Students using screen readers deserve technology that enables them to learn, compete, and succeed on equal terms with their sighted peers. This requires response times under

25ms, which current research shows requires 24-32GB RAM as a minimum, with 32GB+ configurations preferred for true educational equity.

The time for incremental improvements has passed. Educational equity demands immediate action to ensure that all students have access to technology that truly enables their success, not systems that create barriers to their educational achievement.

1.14.5 Laptops Meeting Minimal Educational Requirements

Table 1.6: Comprehensive Modern Laptop Specifications for Accessibility and Performance (2025)

Company	Model	Price (USD)	RAM	Processor	Screen	Brightness (nits)	Contrast Ratio
Microsoft	Surface Laptop 7 Copilot+	$2,000+	32–64GB	Snapdragon X Elite/X Plus (ARM)	13.8”/15” 2496x1664 120Hz Touch	600–650	1500:1 (IPS)
Microsoft	Surface Pro 11 Copilot+	$2,100+	32–64GB	Snapdragon X Elite/X Plus (ARM)	13” OLED/IPS 120Hz Touch	up to 900	1,000,000:1 (OLED)
Dell	Premium	$1,500+	32GB	Snapdragon X Plus (ARM)	13.4” FHD+ 120Hz OLED Touch	500–600	1,000,000:1 (OLED)
Dell	16 Premium	$2,000+	32–64GB	Intel Core Ultra 9 185H	16” up to 4K OLED	400–600	2000:1 (IPS)/1,000,000:1 (OLED)
Dell	14 Plus	$1,000+	16GB	Snapdragon X Plus (ARM)	14” FHD+ IPS	300	1200:1 (IPS)

Continued on next page

Table 1.6: Comprehensive Modern Laptop Specifications for Accessibility and Performance (2025) (Continued)

Company	Model	Price (USD)	RAM	Processor	Screen	Brightness (nits)	Contrast Ratio
Dell	14 Plus	$1,200+	16GB	AMD Ryzen AI 5 340	14” FHD+ IPS	300	1200:1 (IPS)
Dell	14 Pro	$1,700+	up to 32GB	Snapdragon X Elite (ARM)	14” QHD+ Touch IPS	400–500	1500:1 (IPS)
HP	OmniBook Ultra Copilot+ 14	$1,449+	32GB	Snapdragon X Elite (ARM)	14” 2240x1400 Touch	500	1500:1 (IPS)
HP	OmniBook Ultra Flip 14	$1,449+	32GB	AMD Ryzen AI 9 HX 375 / Intel Core Ultra Series 2	14” 2880x1800 OLED 120Hz Touch	500–600	1,000,000:1 (OLED)
HP	EliteBook Ultra Copilot+	$1,800+	up to 32GB	Snapdragon X Elite (ARM)	14” 2240x1400 IPS	400–500	1500:1 (IPS)
Lenovo	Yoga Slim 7x Copilot+	$1,300+	32GB	Snapdragon X Elite (ARM)	14.5” 2944x1840 OLED	up to 1000	1,000,000:1 (OLED)

Continued on next page

Table 1.6: Comprehensive Modern Laptop Specifications for Accessibility and Performance (2025) (Continued)

Company	Model	Price (USD)	RAM	Processor	Screen	Brightness (nits)	Contrast Ratio
Lenovo	ThinkPad T14s Gen 6 Copilot+	$1,700+	32GB	Snapdragon X Elite (ARM)	14" 2240x1400 IPS	400–500	1500:1 (IPS)
ASUS	Zenbook S 14 Copilot+	$1,300+	32GB	Snapdragon X1 Elite (ARM)	14" 2880x1800 OLED	550–600	1,000,000:1 (OLED)
ASUS	Zenbook Duo 14 OLED (2025)	$2,499+	32GB	Intel Core Ultra 9	Dual 14" 3K OLED Touch	500–600	1,000,000:1 (OLED)
MSI	Prestige A16 AI+	$2,299+	32GB	AMD Ryzen AI 9-365	16" 3840x2400 OLED	500–600	1,000,000:1 (OLED)
MSI	Pulse 16 AI Gaming	$2,799+	64GB	Intel Core Ultra 9	16" 2560x1600 QHD 240Hz	350–400	1200:1 (IPS)
Razer	Blade 18 (2025)	$3,500+	32–64GB	Intel Core Ultra 9 275HX	18" QHD+/mini-LED 240/300Hz	up to 1000	1,000,000:1 (mini-LED)
Acer	Aspire 16	$1,499+	32GB	Intel Core Ultra 7 155U	16" 3200x2000 OLED	400–500	1,000,000:1 (OLED)

Continued on next page

Table 1.6: Comprehensive Modern Laptop Specifications for Accessibility and Performance (2025) (Continued)

Company	Model	Price (USD)	RAM	Processor	Screen	Brightness (nits)	Contrast Ratio
Framework	Framework 13	$1,499+	32GB–64GB	Ryzen AI 7	13” 2880x1920 OLED	>500	1,000,000:1 (OLED)
Framework	Framework 16	$1,499+	32GB–64GB	Ryzen 9	16” 2560x1600 QHD+	>500	1500:1 (IPS)

Chapter 2

Transformative Tablets: Pioneering Success for Visually Impaired Students Through Innovative Apps

In an era where technology shapes the landscape of education, tablets have emerged as transformative tools, providing visually impaired students with unprecedented access to knowledge and fostering independence in their academic journeys.[1] Both iPad and Android devices offer user-friendly interfaces and a diverse array of applications specifically tailored to bridge the accessibility gap. This chapter explores how tablets, in tandem with purpose-built apps, are not just tools but catalysts for success in the educational journey of visually impaired students.

Tablets serve as dynamic portals for visually impaired learners, offering a multi-sensory approach to engagement. Their unique functionalities, combined with a robust ecosystem of accessibility apps, empower students to navigate the digital realm with confidence and independence.

2.1 Tablet Considerations

When selecting a tablet for students with visual impairments, consider the following:

[1] I am omitting iPhone and Android phones from this document as the purchase of student phones is beyond the purview of a school district. However, iOS apps are provided as many of these are available on both Tablets and Phones and training students to use the technology on their personal device is often necessary, particularly within the auspice of Orientation & Mobility instruction

- *Accessibility features:* Ensure compatibility with screen readers and magnification tools (e.g., VoiceOver for iOS, TalkBack for Android).[2]
- *Tactile features, size, and weight:* Choose a device that accommodates the student's specific needs.
- *Contrast and color settings:* High contrast and customizable color settings, as well as text-to-speech functionalities, enhance readability.
- *Screen size:* Larger screens can help reduce visual fatigue and improve usability, but balance with portability.
- *App compatibility:* Ensure the device supports a variety of educational and accessibility apps.
- *Visual fatigue:* Avoid prioritizing brightness; instead, focus on resolution and screen area. Adjust luminance for students with photophobia.
- *AI Integration:* Modern tablets now offer enhanced AI-powered accessibility features, including improved object recognition and natural language processing.

Contrast ratio is especially important for students with visual impairments. Understanding and prioritizing contrast ratio helps foster an inclusive and enriching educational environment.

2.2 Tablet Options

When choosing an Android Tablet or iPad for a student with visual impairments, several factors must be considered to ensure that the student receives free and appropriate public education. The first factor to consider is the screen contrast ratio. A high contrast ratio is essential for students with visual impairments as it makes it easier for them to read text and view images on the screen. For Android Tablets, the W3C recommends a contrast ratio of at least 4.5:1 for small text and 3.0:1 for large text[3]. Apple devices continue to excel with their "Increase Contrast" feature and additional accessibility enhancements[4].

The second factor to consider is the size of the screen. A larger screen is beneficial for students with visual impairments as it allows them to view text and images more clearly.

[2] Android accessibility features have significantly improved since 2020, with TalkBack now offering comparable functionality to VoiceOver. However, iOS devices still maintain a slight advantage in terms of app compatibility and developer support for accessibility features.

[3] Google. (n.d.). Color contrast - Android Accessibility Help. Retrieved December 19, 2023

[4] iMore. (n.d.). How to increase contrast for visual accessibility on iPhone and iPad. Retrieved December 19, 2023

Tablets usually have larger screens than smartphones, making them a better choice for students with visual impairments[5]. However, it is important to note that larger screens come at the expense of portability. Therefore, it is essential to find a balance between screen size and portability.

The third factor to consider is the availability of accessible apps. Both Android and iOS devices have built-in accessibility features such as screen readers, magnifiers, and high contrast modes [6,7]. Additionally, there are several apps available that are specifically designed for students with visual impairments. Enhanced AI-powered apps like Be My Eyes now include Be My AI functionality, while SeeingAI continues to evolve with improved object recognition capabilities[8].

Tables 7.1 through 7.4 describe current tablet computers that are available for students with visual impairments.

2.2.1 AndroidOS 14+ Tablets

Table 2.1: AndroidOS 14+ tablets suitable for students with visual impairments (Updated 2025)

Tablet	Screen Size
Google Pixel Tablet	10.9
Samsung Galaxy Tab A9	8.7
Samsung Galaxy Tab A9+	11.0
Samsung Galaxy Tab S9	11.0
Samsung Galaxy Tab S9 FE	10.9

Continued on next page

[5] American Foundation for the Blind. (n.d.). Smartphone or Tablet: Which is Best for You? Retrieved December 19, 2023

[6] American Academy of Ophthalmology. (n.d.). 30 Apps, Devices and Technologies for People With Vision Impairments. Retrieved December 19, 2023

[7] American Foundation for the Blind. (n.d.). Apple iOS for iPhone and iPad: Considerations for Users with Visual Impairments. Retrieved December 19, 2023

[8] American Academy of Ophthalmology. (n.d.). Technology Tools for Children with Low Vision. Retrieved December 19, 2023

Table 2.1: AndroidOS 14+ tablets suitable for students with visual impairments (Updated 2025) (Continued)

Tablet	Screen Size
Samsung Galaxy Tab S9 FE+	12.4
Samsung Galaxy Tab S9 Ultra	14.6
Samsung Galaxy Tab S9+	12.4
Samsung Galaxy Tab S10+	12.4
Samsung Galaxy Tab S10 Ultra	14.6
OnePlus Pad	11.6
OnePlus Pad 2	12.1
Lenovo Tab P12	12.7
Lenovo Tab P12 Pro	12.6
Lenovo Tab M10 Plus (4th Gen)	10.6
Lenovo Tab M11	11.0
Xiaomi Pad 6	11.0
Xiaomi Pad 6 Pro	11.0
Xiaomi Pad 6S Pro	12.4
Honor Pad 9	12.1
Realme Pad 2	11.5
Redmi Pad Pro	12.1
Oppo Pad Air 2	11.4
Vivo Pad 3	12.1

Note: Summary: Comprehensive list of Android tablets running OS 14 or higher, showing model name and screen size in inches

2.2.2 iPadOS Tablets

Table 2.2: iPadOS tablets suitable for students with visual impairments (Updated 2025)

Tablet	Cost	Screen Size
Apple iPad 10.9 (10th Gen)	$349	10.9
Apple iPad Air 11 (M2)	$599	11.0
Apple iPad Air 13 (M2)	$799	13.0
Apple iPad Pro 11 (M4)	$999	11.0
Apple iPad Pro 13 (M4)	$1299	13.0
Apple iPad mini 7 (A17 Pro)	$499	8.3

2.2.3 Windows OS Tablets

Table 2.3: Windows OS tablets suitable for students with visual impairments (Updated 2025)

Tablet	Cost	Screen Size
Microsoft Surface Pro 11	$1199	13.0
Microsoft Surface Pro 10	$1099	13.0
Microsoft Surface Go 4	$629	10.5
Microsoft Surface Laptop Studio 2	$1999	14.4
Dell XPS 13 2-in-1	$1299	13.0
HP Spectre x360	$1149	13.5
Lenovo ThinkPad X1 Tablet	$1449	13.0

Continued on next page

Table 2.3: Windows OS tablets suitable for students with visual impairments (Updated 2025) (Continued)

Tablet	Cost	Screen Size
Asus VivoBook 13 Slate	$849	13.3

2.2.4 ChromeOS Tablets

Table 2.4: ChromeOS tablets suitable for students with visual impairments (Updated 2025)

Tablet	Cost	Screen Size
Lenovo Chromebook Duet 3	$349	11.0
Lenovo Chromebook Duet 5	$449	13.3
HP Chromebook x2 11	$599	11.0
Asus Chromebook CM3	$399	10.5
Acer Chromebook Spin 714	$729	14.0

2.3 Mobile Applications

Mobile apps run on tablets are becoming increasingly important for students with visual impairments to access a free and appropriate public education. These apps can provide students with access to digital content, assistive technology, and other tools that can help them succeed in their studies. High-quality mobile apps can help students with visual impairments access the same educational materials as their sighted peers and participate fully in the curriculum. They can also help improve literacy skills, comprehension, and productivity. In this section, we will explore the importance of high-quality mobile apps for students with visual impairments and discuss some of the best apps available on the market today.

Accessibility Training/Auditory Games

Table 2.5: Mobile apps for accessibility training and auditory games for students with visual impairments (Updated 2025)

App	Cost	Function	OS
CosmoBally in Space	free	Train VoiceOver Gestures	iOS/iPadOS
Ballyland Magic Plus	$4.99	Train VoiceOver Gestures	iOS/iPadOS
Ballyland Rotor	$3.99	Train VoiceOver rotor	iOS/iPadOS
Ballyland Stay Still Squeaky!	$3.99	Train VoiceOver Gestures	iOS/iPadOS
Blindfold Games Launcher	free[12]	Sonic Games	iOS/iPadOS
Blindfold Tap and Swipe	free	Train VoiceOver Gestures	iOS/iPadOS
ObjectiveEd Games	free[12]	Sonic Games	iOS/iPadOS
VO Lab	$5.99	Train VoiceOver Gestures	iOS/iPadOS
Screenreader	free	Train Accessibility Gestures	iOS/iPadOS, Android 14+

2.3.1 Cortical Vision Impairment

Table 2.6: Mobile apps for cortical vision impairment (CVI) training for students with visual impairments (Updated 2025)

App	Cost	Function	OS
Art of Glow	free	CVI-based Vision Training	iOS/iPadOS
Big Band Patterns	$39.99	CVI-based Vision Training	iOS/iPadOS
Big Bang Pictures	$39.99	CVI-based Vision Training	iOS/iPadOS
CVI Connect	$12/mo	CVI-based Vision Training	iOS/iPadOS
CVI Connect Pro	free[16]	CVI-based Vision Training	iOS/iPadOS
CVI Toddler Visual Eye Train	free	CVI-based Vision Training	iOS/iPadOS
CVI Training (Color)	free	CVI-based Vision Training	iOS/iPadOS
CVI Training (Human face)	free	CVI-based Vision Training	iOS/iPadOS
CVI Training (Pattern)	free	CVI-based Vision Training	iOS/iPadOS
CVI Training (Recognition)	free	CVI-based Vision Training	iOS/iPadOS
CVI Training (Visual Tracking)	free	CVI-based Vision Training	iOS/iPadOS

Continued on next page

Table 2.6: Mobile apps for cortical vision impairment (CVI) training for students with visual impairments (Updated 2025) (Continued)

App	Cost	Function	OS
Dexteria VMI	$6.99	CVI-based Vision Training	iOS/iPadOS
EDA Play	$5.99	CVI-based Vision Training	iOS/iPadOS
EDA Play ELIS	$3.99	CVI-based Vision Training	iOS/iPadOS
EDA Play PAULI	$3.99	CVI-based Vision Training	iOS/iPadOS
EDA Play TOBY	free	CVI-based Vision Training	iOS/iPadOS
EDA Play TOM	free	CVI-based Vision Training	iOS/iPadOS
EyeMove	free	CVI-based Vision Training	iOS/iPadOS
Little Bear Sees	$5.99	CVI-based Vision Training	iOS/iPadOS
Peekaboo Barn	$3.99	CVI-based Vision Training	iOS/iPadOS
Sensory Light Box	$4.99	CVI-based Vision Training	iOS/iPadOS
Tap-n-See Now	$3.99	CVI-based Vision Training	iOS/iPadOS
Visual Attention Therapy Lite	free	CVI-based Vision Training	iOS/iPadOS

Note: Summary: Specialized apps designed for CVI training and assessment, including current pricing and supported platforms

2.3.2 Audiobook/Reading

Table 2.7: Mobile apps for audiobook, e-book, and DAISY reading for students with visual impairments (Updated 2025)

App	Cost	Function	OS
Audible	free[35]	Audiobook	iOS/iPadOS, AndroidOS 14+
BARD Mobile	free[36]	e-Book	iOS/iPadOS, AndroidOS 14+
Bookshare Reader	free	DAISY Reader	iOS/iPadOS
Dolphin EasyReader	free	DAISY Reader	iOS/iPadOS, AndroidOS 14+
KNFB Reader (OneStepReader)	$109.99	OCR/Reading	iOS/iPadOS, AndroidOS 14+
Kindle	free[37]	e-Book	iOS/iPadOS, AndroidOS 14+
Libby	free[38]	Audiobook	iOS/iPadOS, AndroidOS 14+
Speech Central	free[39]	Text-to-Speech	iOS/iPadOS, AndroidOS 14+
VoiceDream Reader	$19.99[40]	DAISY Reader	iOS/iPadOS

Productivity/Schoolwork/Optical Character Recognition

Table 2.8: Mobile apps for productivity, schoolwork, and optical character recognition (OCR) for students with visual impairments (Updated 2025)

App	Cost	Function	OS
Aiko	free	AI Speech to text	iOS/iPadOS

Continued on next page

Table 2.8: Mobile apps for productivity, schoolwork, and optical character recognition (OCR) for students with visual impairments (Updated 2025) (Continued)

App	Cost	Function	OS
Ballyland Code 1: Say Hello	$3.99	Auditory Coding	iOS/iPadOS
Ballyland Code 2: Give Rotor	$3.99	Auditory Coding	iOS/iPadOS
Ballyland Code 3: Pick Up	$3.99	Auditory Coding	iOS/iPadOS
Clusiv	free[53]	Online learning platform	iOS/iPadOS
Code Quest	free	Auditory Coding	iOS/iPadOS
Desmos Graphing Calculator	free	Accessible Graphing	iOS/iPadOS, AndroidOS 14+
Desmos Scientific Calculator	free	Accessible Scientific Calculator	iOS/iPadOS, AndroidOS 14+
Envision AI	free[54]	AI-powered OCR	iOS/iPadOS, AndroidOS 14+
GoodNotes 5	$7.99	Scan & Markup Documents	iOS/iPadOS, AndroidOS 14+
Microsoft 365	free[55]	Office Suite	iOS/iPadOS, AndroidOS 14+
Notability	$11.99	Scan & Markup Documents	iOS/iPadOS
SeeingAI	free	Talking Camera	iOS/iPadOS, AndroidOS 14+

Continued on next page

Table 2.8: Mobile apps for productivity, schoolwork, and optical character recognition (OCR) for students with visual impairments (Updated 2025) (Continued)

App	Cost	Function	OS
TapTapSee	free	Talking Camera	iOS/iPadOS, AndroidOS 14+
Voice Control for ChatGPT	free[56]	AI Assistant	iOS/iPadOS, AndroidOS 14+

Orientation & Mobility / Navigation

Table 2.9: Mobile apps for orientation, mobility, and navigation for students with visual impairments (Updated 2025)

App	Cost	Function	OS
Apple Maps	free	Turn by Turn Navigation	iOS/iPadOS
Be My Eyes	free	Visual assistance via volunteers	iOS/iPadOS, AndroidOS 14+
BlindSquare	$49.99	GPS Navigation	iOS/iPadOS
Clew	free	Indoor navigation	iOS/iPadOS, AndroidOS 14+
GoodMaps Explore	free	Indoor/Outdoor navigation	iOS/iPadOS
Google Maps	free	Turn by Turn Navigation	iOS/iPadOS, AndroidOS 14+
Lazarillo	free	GPS navigation	iOS/iPadOS, AndroidOS 14+
Moovit	free[60]	Public Transit	iOS/iPadOS, AndroidOS 14+

Continued on next page

Table 2.9: Mobile apps for orientation, mobility, and navigation for students with visual impairments (Updated 2025) (Continued)

App	Cost	Function	OS
Oko	free	Smart traffic detection	iOS/iPadOS, AndroidOS 14+
Soundscape	free	3D audio navigation	iOS/iPadOS, AndroidOS 14+
Waymap	free	Indoor/Outdoor navigation	iOS/iPadOS, AndroidOS 14+

2.3.3 Independent Living Skills

Table 2.10: Mobile apps for independent living skills for students with visual impairments (Updated 2025)

App	Cost	Function	OS
CashReader	free[70]	Currency identification	iOS/iPadOS, AndroidOS 14+
Lookout	free	AI-powered assistance	AndroidOS 14+
Magnifier	free	Built-in magnification	iOS/iPadOS
Menus4All	free[71]	Restaurant menus	iOS/iPadOS
PenFriend	free	Labeling system app	iOS/iPadOS
Supersense	free[72]	AI scene description	iOS/iPadOS, AndroidOS 14+

Continued on next page

Table 2.10: Mobile apps for independent living skills for students with visual impairments (Updated 2025) (Continued)

App	Cost	Function	OS
Voice Assistant	free	Voice control	iOS/iPadOS, AndroidOS 14+

2.4 Conclusion

The landscape of assistive technology for visually impaired students continues to evolve rapidly, with new applications and enhanced features being released regularly. When selecting tablets and applications for educational use, it is essential to consider the specific needs of each student, the available budget, and the compatibility with existing assistive technologies. Regular updates to both hardware and software ensure that students have access to the most current and effective tools for their educational success.

The integration of artificial intelligence and machine learning in accessibility applications has significantly improved the user experience for visually impaired students. From enhanced object recognition to more accurate optical character recognition, these technological advances continue to break down barriers and provide greater independence in educational settings.

Chapter 3

Bridging Literacy: The Crucial Role of Refreshable Braille Displays in Empowering Visually Impaired Students

In the intricate tapestry of education, the pursuit of literacy is a fundamental thread, weaving through the academic journey of every student. For visually impaired learners, the path to literacy takes on a unique character, one in which the tactile elegance of braille becomes a vital conduit to knowledge. Within this narrative, refreshable braille displays emerge as indispensable companions, unlocking the doors to literacy, fostering engagement, and propelling students toward academic success. This chapter explores how refreshable braille displays are not merely tools but keystones in the quest for literacy and educational achievement among visually impaired students.

Refreshable braille displays integrate the tactile richness of braille with the dynamic capabilities of digital communication. These devices are pivotal in ensuring that visually impaired students not only read but actively participate in the discourse of knowledge acquisition.

Refreshable braille displays serve as conduits for accessing textual content, enabling the exploration of literature, textbooks, and diverse educational materials in a format that aligns with the tactile language of braille. They also empower students to actively contribute to the discourse, facilitating note-taking, writing, and engaging in classroom discussions with the same spontaneity and fluency as their sighted peers.

By providing visually impaired students with the means to interact with written information independently and dynamically, these devices foster a sense of agency and pave the way for academic success.

3.1 Braille Notetakers and Laptops

Braille notetakers such as the BrailleSense6 and BrailleNote Touch Plus are essential tools for students with visual impairments to access their schoolwork and receive a free and accessible public education. These devices are small and portable, allowing students to take notes in class using either braille or standard (QWERTY) keyboard, or both. They can also be used to read books, write class assignments, find directions, record lectures, and listen to podcasts. The notes written on these devices can be transferred to a computer for storage or printed in either braille or print formats. Many note-taking devices have word processors, appointment calendars, calculators or clocks, and can do almost everything a computer can do. Some note-taking devices have a speech program with braille input. Many newer models are Bluetooth accessible which allows them to be used with iPads, iPhones and other Bluetooth devices as well as Wi-Fi access. Braille notetakers are useful not only for note taking in class, but also for composing and printing essays, writing notes, sending e-mails, or browsing the Internet. These devices can give students who are blind or have low vision support in all academic areas as well as in expanded core curriculum. By providing students with visual impairments access to braille notetakers, we can help ensure that they have the tools they need to succeed in their studies and beyond.

Table 3.1: Braille notetakers and laptops: device and operating system

Device Name	Operating System
BrailleNote Touch+	Android 8
BrailleSense 6	Android 12
BTSpeak Pro	Linux
Canute Console	Rasperian 12
ElBraille 40	Windows 10
InsideONE+	Windows 11

Continued on next page

Table 3.1: Braille notetakers and laptops: device and operating system (Continued)

Device Name	Operating System
Nattiq Note	Windows 11
Notey the Notetaker	Windows 11
Orbit Optima	Windows 11
Seika Studio	Windows 10
b.note	Windows 10
b.book	Windows 10

3.2 Braille Notetaker/Laptop Recommendations

The BrailleNote Touch Plus runs on Android 8.1 Oreo, while the BrailleSense 6 now runs on Android 12 following the V2.0 firmware update released by HIMS[1]. While the BrailleSense 6 has received this important update, the BrailleNote Touch Plus remains on an outdated operating system. As of July 7, 2025, Android 16 is the current version of the Android operating system[2].

Using outdated operating systems can pose a security risk, as they no longer receive security updates. This makes it easier for harmful viruses, spyware, and other malicious software to gain access to your device. Hackers often target outdated operating systems because of their vulnerability, allowing them to breach your device and gain personal information. Preventing malicious access to hardware is one major reason why drivers and applications are made back-compatible only to versions of the operating system still receiving security updates.

It is important to keep your operating system up-to-date to ensure that you have access to the latest features and improvements. This can help improve the performance of your device and ensure that it is compatible with the latest software and hardware. Updating your operating system is a simple and effective way to keep your device running smoothly and securely.

[1] HIMS Released the BrailleSense 6 V2.0 update in 2024, upgrading the device from Android 10 to Android 12 Release Notes

[2] Android 16 was released in stable version on June 10, 2025 for Pixel phones, with broader rollouts following

However, updating an operating system is not always possible, as it depends on the device's hardware and software compatibility. It is also important to note that updating to the latest operating system may not always be the best option, as it may cause compatibility issues with older software and hardware.

Table 3.2 gives the recommendations for currently available braille notetakers. An important note is that I favor Windows-based systems, though the BrailleSense 6 with its Android 12 update represents a significant improvement in security and compatibility compared to devices still running older Android versions.

Table 3.2: Braille notetaker and laptop recommendations with key specifications

Display	Battery	Keyboard	Manufacturer	OS
BrailleSense 6	18h	Perkins	HIMS	Android 12
Orbit Optima	TBD	QWERTY	Orbit Research	Windows 11
Seika Studio	TBD	QWERTY	Nippon Telesoft	Windows 10
b.book	15h	Perkins	Eurobraille	Windows 10

3.3 Refreshable Braille Displays

Refreshable braille displays are essential tools for students with visual impairments to access digital content. The number of braille cells in a display is an important factor to consider when selecting a device. Displays with 32-40 cells are generally better than those with 14-20 cells for several reasons. Firstly, they provide more space for displaying text, which can help reduce the need for scrolling and improve reading speed. Secondly, they allow for more complex formatting, such as tables and graphs, which can be important for STEM subjects. Thirdly, they provide more context for the user, which can help improve comprehension and reduce errors. Fourthly, they are more versatile and can be used for a wider range of tasks, such as taking notes, writing essays, and browsing the internet. Finally, they are more future-proof, as they are more likely to be compatible with new technologies and software updates. While 14-20 cell displays may be more affordable, investing in a 32-40 cell display can provide significant benefits for students with visual impairments in the long run.

3.3.1 14-20 cell Refreshable Braille Displays

There are some situations where 14-20 cell displays may be more appropriate. For example, if the student only needs to read short messages or simple documents, a smaller display may be sufficient. Additionally, smaller displays are more portable and can be easier to carry around. They may also be more affordable, which can be important for students on a tight budget. Finally, smaller displays may be more appropriate for younger students who are just learning braille and may not need as much space for displaying text. While 14-20 cell displays may not be as versatile as larger displays, they can still provide significant benefits for students with visual impairments in certain situations.

Table 3.3: 14-20 cell refreshable braille displays: device and battery life

Device Name	Battery Life
Actilino	16 hours
Basic Braille 20	16 hours
Brailliant BI20x	14 hours
Chameleon 20	14 hours
Focus 14 Blue	18 hours
Orbit Reader 20+	20 hours
Orbit Speak	20 hours
BTSpeak	15 hours
Seika 24	20 hours
Seika Mini Plus	20 hours
VarioUltra 20	12 hours
b.note 20	15 hours

3.3.2 32-40 cell Refreshable Braille Displays

Displays with 32-40 cells provide more space for displaying text, allow for more complex formatting, and are more versatile for a wider range of tasks. While 14-20 cell displays may be more affordable, investing in a 32-40 cell display can provide significant benefits for students with visual impairments in the long run.

Table 3.4: 32-40 cell refreshable braille displays: features and manufacturers

Display	Battery	Keyboard	Manufacturer
Activator	40	Perkins	Help Tech
Active Braille	20	Perkins	Help Tech
Active Star	40	Perkins	Help Tech
Alva 640 Comfort	10	Perkins	Optelec
Alva 640 USB	n/a	none	Optelec
Alva BC 640	10	none	Alva
Basic Braille Plus	12	Perkins	Help Tech
Brailliant BI40x	14	Perkins	Humanware
Focus 40 Blue	18	Perkins	Vispero
Mantis Q40	14	QWERTY	APH
Orbit Reader 40	20	Perkins	Orbit Research
QBraille XL	16	Perkins	HIMS
Seika V5	20	none	Nippon Telesoft
Vario 340	20	none	VisioBraille
Vario 440	20	none	VisioBraille
Vario Ultra 40	12	Perkins	VisioBraille

Continued on next page

Table 3.4: 32-40 cell refreshable braille displays: features and manufacturers (Continued)

Display	Battery	Keyboard	Manufacturer
b.note 40	15	Perkins	Eurobraille

3.4 Multiple Line Braille Displays/Tablets

Multiple line braille displays are better than single line refreshable braille displays for students with visual impairments for several reasons. Firstly, they provide more space for displaying text, which can help reduce the need for scrolling and improve reading speed. Secondly, they allow for more complex formatting, such as tables and graphs, which can be important for STEM subjects. Thirdly, they provide more context for the user, which can help improve comprehension and reduce errors. Fourthly, they are more versatile and can be used for a wider range of tasks, such as taking notes, writing essays, and browsing the internet. Finally, they are more future-proof, as they are more likely to be compatible with new technologies and software updates. While single line refreshable braille displays may be more affordable, investing in a multiple line display can provide significant benefits for students with visual impairments in the long run.

Table 3.5: Multiple line braille displays and tablets: features and manufacturers

Display	Battery	Braille Lines	Keyboard	Manufacturer
APH Monarch	11 hr	10 row x 32 cell + 32 cell line	Perkins	Humanware, APH
Blitab	TBD	14 row x 23 cell	Touch Interface	Blitab
BraillePad	TBD	50 row x 40 cells	none	4Blind
Cadence	TBD	6 row x 8 cells, stack to 24 x 16	Perkins	Tactile Engineering
Canute 360	Req AC	9 row x 40 cell	none	Bristol Braille

Continued on next page

Table 3.5: Multiple line braille displays and tablets: features and manufacturers (Continued)

Display	Battery	Braille Lines	Keyboard	Manufacturer
DotPad	11 hr	10 row x 32 cell + 20 cell line	Touch interface	Dot Inc.
Graphiti	20-22	60 row x 40 cell	Perkins	Orbit Research
Graphiti Plus	20-22	60 row x 40 cell + 40 cell line	Perkins	Orbit Research
Orbit Slate 340	20-22	5 row x 20 cell	Perkins	Orbit Research
Orbit Slate 520	20-22	5 row x 20 cell	Perkins	Orbit Research
TACTIS 100	Req AC	4 row x 25 cell	none	Tactisplay
TACTIS Table	Req AC	25 row x 40 cell	none	Tactisplay
TACTIS Walk	Req AC	10 row x 25 cell	none	Tactisplay
Tactile Pro	TBD	TBD	Perkins	PCT
Tactonom Pro	Req AC	89 row x 119 cell	N/A	Tactonom

3.5 Braille Education Devices

In many cases, students do not learn braille as efficiently as their sighted peers learn print. One potential explanation is that there is limited time that a student has access to a teacher trained in braille. One solution is to provide devices that can be used to reinforce or train a student in braille skills without the need for a braille-fluent adult present. This is analogous to the Lexia, Prodigy, or other academic learning systems that allow for self-paced learning. In the last 5 years, a number of teaching tools have been developed, primarily by groups in India and South Korea to address these needs.

Specialized tools like Taptilo and Polly/Annie are crucial for teaching Braille to students with visual impairment. These tools provide a more interactive and engaging learning experience for students, which can help them learn Braille more effectively. Taptilo is a Braille learning device that uses a modular design to teach Braille in a fun and interactive way. It has a variety of features such as audio feedback, games, and quizzes that can help students learn Braille more effectively[3]. Polly and Annie are two Braille teaching tools that use a combination of hardware and software to teach Braille to students. They use a variety of interactive games and activities to help students learn Braille more effectively[4].

In addition to providing a more engaging learning experience, specialized tools like Taptilo and Polly/Annie can also help students learn Braille more quickly. These tools are designed to be intuitive and easy to use, which can help students learn Braille more quickly than traditional methods. Additionally, these tools can provide students with immediate feedback on their progress, which can help them identify areas where they need to improve.

Finally, specialized tools like Taptilo and Polly/Annie can help students with visual impairment become more independent. By learning Braille more effectively and quickly, students can become more independent in their daily lives. They can read books, take notes, and communicate with others more easily, which can help them lead more fulfilling lives.

Table 3.6: Braille education devices and their manufacturers

Equipment	Manufacturer
Braille Doodle	Touchpad Pro Foundation
Braille Teach	Braille Teach
BrailleBlox	BrailleBot
BrailleBuzz	APH
BrailleCoach	Logan Tech
Feelif Creator	Feelif Technology
Feelif Pro	Feelif Technology

Continued on next page

3 Taptilo. (n.d.). Taptilo. Retrieved December 19, 2023 https://www.taptilo.com/
4 Thinkerbell Labs. (n.d.). Polly. Retrieved December 19, 2023 https://www.thinkerbelllabs.com/

Table 3.6: Braille education devices and their manufacturers (Continued)

Equipment	Manufacturer
Mountbatten Braille Tutor	Harpo
Polly[8]	APH / Thinkerbell Labs
Read Read	EdVar Tech
SMART Brailler	Perkins
Taptilo	HIMS / OHFA Tech

Chapter 4

Empowering Minds: The Crucial Role of High-Quality Braille Embossers in Unlocking STEM Literacy for Visually Impaired Students

In the ever-evolving realms of Science, Technology, Engineering, and Mathematics (STEM), the pursuit of literacy takes on a particularly intricate form. For visually impaired students, the challenges are multifaceted, but with the advent of high-quality braille embossers, a transformative bridge has been constructed. This chapter explores the indispensable role that high-quality braille embossers play in shaping the educational narrative of visually impaired students, especially in the critical domains of Math and STEM. These devices, with their ability to translate complex symbols and notations into tangible braille and tactile graphics, foster literacy, comprehension, and success in STEM fields.

The crux of this exploration lies in recognizing the nuanced requirements of visually impaired students pursuing education in Math and STEM disciplines. Traditional print materials, laden with intricate diagrams, mathematical symbols, and graphs, pose formidable challenges for learners with visual impairments. High-quality braille embossers bridge this gap, converting abstract mathematical concepts and scientific data into tangible formats, empowering students to actively engage with and comprehend the intricacies of STEM subjects.

Embossed tactile graphics break down the barriers to understanding complex mathematical equations, graphical representations, and scientific concepts, ultimately fostering a sense of autonomy and empowerment among visually impaired students. By providing access to the visual nuances inherent in STEM fields, these devices pave the way for literacy, comprehension, and active participation, ensuring that visually impaired students can unlock the full spectrum of opportunities in Math and STEM disciplines.

4.1 Braille Embossers

Having access to a high-quality braille embosser is essential for students with visual impairments to receive a free and appropriate public education. Braille embossers are printers that produce braille text and tactile graphics on paper. They are used to create braille copies of textbooks, worksheets, and other educational materials. High-quality embossers produce sharp, clear braille that is easy to read and tactile graphics that are easy to interpret. This is important because it allows students with visual impairments to access the same educational materials as their sighted peers. Braille embossers also allow students to create their own braille notes and written work, which can help improve their literacy skills and independence. By providing students with visual impairments access to high-quality braille embossers, we can help ensure that they have the tools they need to succeed in their studies and beyond. *Table 4.1* lists current available embossers[1].

Table 4.1: Braille embosser comparison: machine, capability, and company (Updated 2024-2025)

Machine	Capability	Company
APH PageBlaster (Index-D V4)	Simple Graphics, Interpoint Braille	APH, Index Braille
Basic-D V5	Simple Graphics, Interpoint Braille, 16.7 lbs portable	Index Braille
Braille Box V5	Production Braille, Advanced Technology	Index Braille

Continued on next page

1 I am only focusing on 11x11.5" braille paper size as US Letter size is impractical for braille

Table 4.1: Braille embosser comparison: machine, capability, and company (Updated 2024-2025) (Continued)

Machine	Capability	Company
BrailleTrac 120	Simple Graphics, Interpoint Braille	Irie-AT
Juliet 120	Simple Graphics, Interpoint Braille	ETS, Humanware
ViewPlus Columbia	Complex Graphics, Interpoint Braille	ViewPlus
ViewPlus Max (formerly Rogue)	Complex Graphics, Interpoint Braille, 8 dot heights	ViewPlus
ViewPlus Premier	Complex Graphics, High-speed (100 CPS), Production	ViewPlus
ViewPlus Delta 2	Complex Graphics, Power-Dot Braille, 120 CPS	ViewPlus
Marathon Brailler	High-speed single-sided, 200 CPS	HumanWare
Mountbatten Brailler	Electronic braille embosser	HumanWare

4.2 High Resolution Tactile Graphics

There are some historical challenges that have befallen blind students that rely on tactile graphics and braille.

- Historically, by the time students with visual impairments enter school, they have not received enough instruction in the development and use of their tactile skills or had enough opportunities to touch and explore their world.[2]

[2] Adkins, A., Sewell, D., & Cleveland, J. (2016). The Development of Tactile Skills. TX *SenseAbilities, Fall/Winter*.

- Tactile Graphicacy requires the ability to access, comprehend, and produce tactile graphics or raised line drawings. This requires:
    - Fine motor sensitivity and dexterity
    - Efficient use of carefully constructed knowledge
    - Variety of tactile-cognitive strategies
- Students have to develop a perception that there are different kinds of symbolic information on a page with different kinds of meaning
- Students have to develop an ability to discriminate between different tactile surfaces and to draw meaning from them
- These are *not* inherent or natural for braille readers as they require:
    - Explicit attention
    - Education
    - Careful, systematic building of tactile exploratory and interpretive skills

Recent advances in tactile graphics technology have introduced AI-generated tactile graphics systems that can automatically convert visual information into tactile formats while adhering to Braille Authority of North America (BANA) guidelines. These developments promise to address the traditional labor-intensive production methods that have limited scalability of tactile graphics creation.

There are a number of benefits to having access to accessible tactile graphics in the classroom. These include:

- Provides a focus for attention and perception
- Builds pathways to retain and memorize information
- Natural destination for conversation and social interaction
- Pictures invite and motivate a learner's curiosity and engagement
- Modern embossers with multiple dot heights (up to 8 different levels) allow for more sophisticated tactile representations

Table 4.2 lists current available embossers and other devices for creation of high resolution tactile graphics.

Table 4.2: High resolution tactile graphics embossers: machine and company (Updated 2024-2025).

Machine	Company	Special Features
APH PixBlaster (ViewPlus Columbia)	APH, ViewPlus	High-resolution tactile graphics
Basic-D V5	Index Braille	Portable, simple graphics
Braille Box V5	Index Braille	Production-level, advanced technology
EZ-Form Brailon Duplicator	American Thermoform	Thermoform duplication
PIAF tactile embosser	Humanware	Capsule paper technology
Swell Form Machine	American Thermoform	Swell touch paper
ViewPlus Columbia	ViewPlus	Complex graphics, desktop model
ViewPlus Delta 2	ViewPlus	Power-Dot Braille, 120 CPS
ViewPlus Elite	ViewPlus	High-end production model
ViewPlus Max	ViewPlus	8 dot heights, desktop tactile graphics
ViewPlus Premier	ViewPlus	100 CPS, production strength

Specialized embossers for high-resolution tactile graphics production, listing available models with enhanced capabilities and specifications.

4.3 Tactile Graphic Supplies

The advancement in tactile graphics technology has also led to improvements in specialized media and supplies. Modern production environments benefit from enhanced paper feeding systems, with tractor-feed technology providing the most reliable sheet handling for continuous production. *Table 4.3* lists materials needed to use with the graphics devices shown in *Table 4.2*.

Table 4.3: Paper supplies for Tactile Graphics Generation (Updated 2024-2025)

Paper / Medium	Company	Compatible Devices
Brailon Thermoform Paper	American Thermoform	EZ-Form Duplicator
Swell Touch Paper	American Thermoform	Swell Form Machine
Tangible Magic Capsule Paper	Humanware	PIAF tactile embosser
Tractor-Feed Braille Paper	APH	Production embossers
High-Resolution Tactile Paper	ViewPlus	ViewPlus embosser series
11x17 Tactile Graphics Paper	Various	Large format tactile graphics

4.4 Market Trends and Future Developments

The braille embosser market has experienced significant growth, with major players including A11yTech, Tobii Dynavox, Perkins Solutions, Freedom Scientific, and HumanWare. Recent market analysis indicates sustained demand for both educational and institutional applications, with government institutions representing a significant market segment.

Current technological developments focus on improving production speeds, with some industrial models capable of output rates exceeding 200 characters per second. The integration of advanced software suites, such as the TIGER software suite included with ViewPlus systems, has streamlined the process of creating tactile graphics from standard documents.

The emergence of AI-powered tactile graphics generation represents a paradigm shift in the field, potentially addressing the scalability challenges that have historically limited access to tactile materials. These systems can automatically convert visual content while maintaining adherence to established accessibility standards, promising to democratize access to tactile graphics across educational institutions.

Educational institutions continue to recognize the critical importance of these technologies in providing equitable access to STEM education. The combination of high-speed braille production capabilities with sophisticated tactile graphics generation ensures that visually impaired students can engage with complex mathematical and scientific concepts at the same pace as their sighted peers.

Chapter 5

Shaping Knowledge: The Imperative Role of 3D Printed Materials in Fostering Hands-On Literacy for Visually Impaired Students

In the realm of education, the power of hands-on experience is unparalleled. For visually impaired students, the journey toward literacy and comprehension takes on a unique dimension—one that is enriched and transformed through the tactile exploration of 3D printed materials. This chapter explores the indispensable role that 3D printed materials play in providing a tangible, tactile bridge to knowledge. These innovative creations facilitate hands-on engagement with concepts and serve as catalysts for literacy, fostering success for visually impaired students across a diverse spectrum of subjects.

The need for tangible exploration is paramount, especially when conceptualizing abstract ideas or interacting with physical entities is integral to the learning process. Traditional educational materials often rely on visual cues that pose challenges for students with visual impairments. 3D printed materials transcend the limitations of traditional teaching tools and enhance literacy by providing a multisensory gateway to understanding.

From historical artifacts to mathematical models, 3D printed materials transform abstract concepts into tangible, touchable entities. These creations allow visually impaired students to feel, explore, and internalize knowledge in a manner that aligns with their unique learning styles.

Hands-on learning with 3D printed materials fosters comprehension, empowerment, and curiosity. These tools democratize access to knowledge and enhance the educational journey for visually impaired students.

5.1 3D Printers

When selecting a 3D printer for students with visual impairments, it is important to consider the following features:

- *Tactile printing:* The printer should produce 3D models that are tactile and easily understood by students with visual impairments.
- *High resolution:* The printer should produce high-resolution models with fine details.
- *Ease of use:* The printer should be easy to use, set up, and maintain.
- *Compatibility:* The printer should be compatible with a wide range of software and file formats.
- *Cost:* The printer should be affordable and within the school or institution's budget.
- *Safety features:* Enclosed designs and automatic bed leveling for safer operation in educational environments.
- *Reliability:* Consistent performance with minimal maintenance requirements.

3D printing can help visually impaired students learn a variety of disciplines such as engineering, manufacturing, food, art, and health.[1] 3D printed models can benefit both blind and sighted students, allowing for multisensory learning and independence.[2]

Table 5.1 lists current available 3D printers with updated pricing.

Table 5.1: Comparison of 3D printers: model, cost, print bed size, filament size, and manufacturer

Model	Cost	Print Bed Size	Filament Size	Manufacturer
Bambu A1 Mini	$249	180x180x180mm	1.75mm	Bambu Lab

Continued on next page

[1] Karbowski, C. F. (2020). See3D: 3D Printing for People Who Are Blind. Journal of Science Education for Students with Disabilities, 23(1), n1.

[2] MatterHackers. (2017). 3D printed educational models for the visually impaired. MatterHackers

Table 5.1: Comparison of 3D printers: model, cost, print bed size, filament size, and manufacturer (Continued)

Model	Cost	Print Bed Size	Filament Size	Manufacturer
Elegoo Neptune 3 Pro	$170	225x225x280mm	1.75mm	Elegoo
Creality Ender-3 V3 KE	$269	220x220x250mm	1.75mm	Creality
Ender 3 Max Neo	$389	300x300x320mm	1.75mm	Creality
Ender 5 Plus	$629	350x350x400mm	1.75mm	Creality
Creality K1	$649	220x220x256mm	1.75mm	Creality
Anycubic Kobra Max	$619	450x400x400mm	1.75mm	Anycubic
Anycubic Kobra Plus	$549	300x300x350mm	1.75mm	Anycubic
AnkerMake M5C	$429	220x220x250mm	1.75mm	AnkerMake
Prusa Mini+	$499	180x180x180mm	1.75mm	Prusa
Elegoo Neptune 3 Max	$520	420x420x500mm	1.75mm	Elegoo
Elegoo Neptune 4 Pro	$380	225x225x265mm	1.75mm	Elegoo
Anycubic Kobra S1 Combo	$829	220x220x270mm	1.75mm	Anycubic
Artillery Sidewinder X2	$449	300x300x396mm	1.75mm	Artillery

Table 5.2: Premium 3D printers: model, cost, print bed size, filament size, and manufacturer.

Model	Cost	Print Bed Size	Filament Size	Manufacturer
Bambu P1P	$749	256×256×256mm	1.75mm	Bambu Lab
Bambu P1S (Combo)	$699	256×256×256mm	1.75mm	Bambu Lab
Bambu X1C Carbon (Combo)	$1,299	256×256×256mm	1.75mm	Bambu Lab
Bambu A1	$599	256×256×256mm	1.75mm	Bambu Lab
Prusa MK4	$829	250×210×220mm	1.75mm	Prusa
Prusa MK4 Kit	$749	250×210×220mm	1.75mm	Prusa
Prusa Core ONE	$1,299	250×220×270mm	1.75mm	Prusa
Creality K2 Plus	$1,299	350×350×400mm	1.75mm	Creality
Creality K2 Plus (with CFS)	$1,499	350×350×400mm	1.75mm	Creality

5.2 Web Resources for 3D Print Files and Accessibility

Designed For VI Specifically

- BTactile, Benetech ImageShare, Median Augenbit, Tactiles, See3D, Accessible3D

Math Curricula

- Nonscriptum Calculus, Geometry, Trigonometry, Tactile Math Models

Astronomy/Physics

- 3D Opal, Astrokit, NASA, Roving Bits Constellations, Tactile Universe, ESA 3D Models

Biology

- 3D Biology, NIH 3D Print Collections/Models, Tactile Anatomy Models

General User-Uploaded 3D Print File Collections

- Printables, Thingiverse, My Mini Factory, Cults 3D, Thangs, MakerWorld, GrabCad, Instructables, Pinshape, Sketchfab, 3D Warehouse, Traceparts, Turbo Squid, YouMagine

3D File Search Aggregators

- Thangs3D, Yeggi, 3D Find It, 3D Print Shelf, 3DSourced, STL Finder, STLBase, MakerOnline, Mito3D, Open 3D Model, SeekSTL, Creazilla, Free3d

AI 3D Model Generation

- Meshy.ai, Luma AI Genie, Sloyd, Kaedim, Spline AI, Masterpiece Studio, 3D AI Studio

Professional Groups

- AT Makers, Makers Making Change, Enabling the Future, Thingiverse Assistive Technology

Visually Impaired Education and Accessibility Resources

- See3D, Accessible3D, MatterHackers Education, Braille Institute, American Foundation for the Blind, Paths to Literacy, 3D Print Accessibility Community

5.3 3D Printer Materials

3D printing creates three-dimensional objects from computer-aided design (CAD) files. The process involves depositing materials layer by layer to build a shape.[3] To use a 3D printer in an educational environment, you need:

- *3D printer*: Available in various sizes, from benchtop to large-format, including models with enclosures/environmental control for improved reliability.
- *Filament*: The material used to create the 3D object (e.g., PLA, TPU, ABS, PETG, etc.).[4]
- *Computer*: Required to create the 3D model using CAD software.

[3] Dassault Systèmes. (n.d.). 3D printing in education. Retrieved December 19, 2023
[4] Tech & Learning. (2023). Best 3D printers for schools. Retrieved December 19, 2023

- *CAD software*: Used to create the 3D model.
- *Slicing software*: Converts the 3D model into a format the printer can understand and generates the G-code for printing.[5]

3D Printer Filament (PLA) and Color Resources

FilamentColors is a color checking program for popular PLA vendors, providing Hex codes for reproducible color accuracy. Not all vendors are available, but the list is growing.

Prices are for 1kg/2.2lb basic PLA, default with spool unless noted. Refills require a spool. Current pricing reflects market conditions as of July 2025, including tariff impacts on non-US suppliers.

International Suppliers (prices affected by tariffs):

- Bambu Labs: $28 ($23 with 4+ rolls) with spool; $25 ($20 with 4+ kg) for refills
- Creality: $22 Soleyin Ultra PLA; $25 Ender Fast PLA
- ELEGOO: $18
- eSun: $24
- Sunlu: $25
- Polymaker: $26
- OVERTURE: $22

Manufactured in the USA (minimal tariff impact): Most US PLA is sourced from Natureworks LLC (Ingeo Line).

- Polar Filament: $19 (Basic PLA), $22 (Premium colors)
- 3D Fuel: $27
- American Filament: $27 ($14 500g refill)
- Atomic Filament: $32
- Hatchbox: $24
- MatterHackers: $20+
- Overture 3D: $25
- Polymaker: $22
- ProtoPasta: $21

5 TeachThought. (2021). 10 ways 3D printing can be used in education. Retrieved December 19, 2023

- Push Plastic: $26
- Printed Solid: $26
- Filastruder: $11 PLA, $13 PLA Pro
- Splice 3D: $17/spool (bulk: $14 w/4+, $12 w/8+, $11 w/24+)
- ZYLTech: $19
- Gizmo Dorks: $25
- IC3D: $31
- Keene Village Plastics: $32
- Numakers: $22
- Paramount 3D: $24 ($21/8pack)
- VoxelPLA: $18
- Toner Plastics: $24

Table 5.3 lists materials needed to use the 3D printers shown in Table 5.1.

Table 5.3: 3D Printer Materials

Item	Cost	Vendor
1.75mm filament (see above)	$18–$45/kg	Multiple (Bambu, Elegoo, Polar, 3D Fuel, etc.)
3D Print Tool Kit	$65.00	HIJIRH, Amazon
Assorted Sandpaper (48 pcs)	$9.00	Vicien, Amazon
Glue Sticks (30 pack)	$12.00	Amazon Basics
Painter’s Tape (2” width 12 Pack)	$48.00	Amazon
Build Surface Cleaner	$8.00	Various
Nozzle Cleaning Kit	$15.00	Various

5.4 3D Printer Software

3D printing software allows users to create, edit, and slice 3D models. These programs enable users to design models, slice them into layers, and generate G-code for the printer.

Resources for Programs to Create 3D Models

Free:

- Tinkercad: Browser-based, beginner-friendly, block-building interface.
- Fusion 360: Free for personal/educational use, professional features.
- FreeCAD: Open-source parametric modeler, improving rapidly.
- Blender: Open-source, steep learning curve, excellent for complex models.
- SketchUp Free: Web-based, good balance of usability and functionality.
- OpenSCAD: Script-based modeling, ideal for programmers.
- BRL-CAD: Advanced solid modeling, used by U.S. military.
- Wings3D: Open-source polygon modeler.
- 3D Slash: Fun, voxel-based interface.

Education Plans:

- Fusion 360: Free for students/educators, $60/month otherwise.
- SolidWorks: Educational licenses available, $99/year for students.
- Inventor: Educational pricing available.
- Shapr3D: Educational discounts available.

Professional:

- SolidWorks: $1,395/yr or $4,195 perpetual.
- Inventor: $2,085/yr.
- Rhino3D: $1,095, $195 student.
- 3DS Max: $1,645/yr.
- Maya: $1,645/yr.
- Cinema 4D: $770/yr or $4,195 perpetual.
- Modo: $639/yr or $1,909 perpetual.

3D Print Slicing Programs

- Bambu Studio: Default for Bambu Lab printers, advanced features.
- PrusaSlicer: Free, excellent for most FDM printers.
- Ultimaker Cura: Free, widely compatible.
- OrcaSlicer: Free, community-developed with advanced features.
- Simplify3D: $149, commercial slicer with support.
- IdeaMaker: Free, by Raise3D.
- Repetier-Host: Free, includes slicing and printer control.
- KISSlicer: Free version available.
- 3DPrinterOS: Cloud-based slicing and management.

Table 5.4 lists software and their functions with updated pricing.

Table 5.4: 3D Printer Software and Functions

Program	Cost	Function
Tinkercad	Free	Generate 3D file
Fusion 360	Free (Education)/$60/month	Generate 3D file
FreeCAD	Free	Generate 3D file
SolidWorks	$1,395/yr/$99 student	Generate 3D file
SketchUp Free	Free	Generate 3D file
Blender	Free	Generate 3D file
Rhino 7	$1,095/$195 student	Generate 3D file
Bambu Studio	Free	Slice & Print 3D Model
PrusaSlicer	Free	Slice & Print 3D Model
Ultimaker Cura	Free	Slice & Print 3D Model

Continued on next page

Table 5.4: 3D Printer Software and Functions (Continued)

Program	Cost	Function
OrcaSlicer	Free	Slice & Print 3D Model
Simplify3D	$149	Slice & Print 3D Model
Meshmixer	Free	Fix & Modify 3D Print Files
Meshlab	Free	Fix & Modify 3D Print Files
Netfabb	Free (Basic)	Fix & Modify 3D Print Files

5.5 Recent Developments in 3D Printing for Accessibility

The field of 3D printing for visually impaired education continues to evolve rapidly. Recent developments include improved tactile design guidelines, better integration with assistive technologies, and enhanced software accessibility features. Educational institutions are increasingly recognizing the transformative potential of 3D printing technology for creating inclusive learning environments.

Key trends include:

- Integration of AI tools for automatic generation of tactile models
- Development of specialized software with screen reader compatibility
- Increased collaboration between accessibility organizations and 3D printing communities
- Growing libraries of pre-designed accessible educational models
- Enhanced safety features in educational 3D printers

The market growth in 3D printing technology continues to drive down costs while improving accessibility, making these tools more available to educational institutions serving visually impaired students.

Chapter 6

Amplifying Vision: The Vital Role of Video Magnification Products in Fostering Literacy and Success for Visually Impaired Students

In the realm of visual impairment, the quest for literacy and academic success is a journey characterized by innovation and adaptability. For visually impaired students, the challenge of accessing printed materials, charts, and visual content is met with a powerful solution—video magnification products. The indispensable role that video magnification plays in providing enhanced visual access, breaking down barriers to literacy, and empowering students to navigate the educational landscape with confidence cannot be overstated.

The significance of video magnification products lies in their ability to transform the visual experience for students with visual impairments. As we navigate this chapter, we will unravel the sophisticated functionalities of these devices, showcasing how they go beyond traditional magnification methods to provide an immersive and dynamic visual experience. Whether exploring the pages of a textbook, deciphering intricate diagrams, or engaging with digital content, video magnification stands as a technological ally, ensuring that every student can access and interpret visual information with ease.

The video magnification market has experienced substantial growth, with the assistive technologies for visual impairment market valued at USD 125.84 million in 2023 and projected to reach USD 134.21 million in 2024, eventually growing to USD 224.58 million by 2032. This growth is driven by technological advancements including artificial intelligence integration, augmented reality capabilities, and enhanced portability features that make these devices increasingly accessible to students.

In the pursuit of literacy, the role of video magnification becomes increasingly pivotal, particularly in subjects where visual content is integral to comprehension. This chapter will delve into how these products facilitate not only enhanced readability but also active participation in classroom discussions, visual learning activities, and the overall educational experience. Modern video magnification devices now incorporate AI-powered features such as JAWS Picture Smart AI, which provides detailed image descriptions, revolutionizing accessibility for visually impaired students.

By providing visually impaired students with a clear and magnified view of the visual world, video magnification products serve as gateways to knowledge, fostering a sense of inclusion and leveling the playing field in academic settings. It is evident that these tools are not mere aids; they are essential components in the arsenal of resources necessary for the success of visually impaired students. Video magnification imperatively contributes to shaping a learning environment where visual content is accessible to all, ensuring that literacy and success are attainable goals for every student, regardless of their visual abilities.

6.1 Video Magnification Devices

When purchasing electronic portable magnifiers for students with visual impairments, it is important to consider the following factors to ensure that they can access a free and appropriate public education[1]:

- *Magnification power*: The magnification power of the magnifier should be appropriate for the student's needs. Some magnifiers have a fixed magnification, while others have adjustable magnification. Modern systems can magnify content from 2x to 85x times its original size while maintaining perfect focus.
- *Portability*: Portable magnifiers are ideal for students who need to move around the classroom or school. They should be lightweight and easy to carry. Battery life is an important consideration for portable magnifiers. The battery should last long enough to get through a school day without needing to be recharged.
- *Ease of use*: The magnifier should be easy to use and adjust. It should have large buttons and controls that are easy to locate and operate. Compatibility with other

[1] *cf*., Perkins School for the Blind. (n.d.). Choosing an appropriate video magnifier. Retrieved December 19, 2023

assistive technology devices, such as screen readers and braille displays, is also important.

- *AI and Advanced Features*: Latest trends in low vision magnifiers for 2024 include AI integration, augmented reality, wearable devices, and enhanced connectivity features, which can significantly enhance the learning experience for students.
- *Cost*: The cost of the magnifier should be reasonable and within the school's budget. The American Recovery Plan Act provides funds to libraries and schools to address student learning loss and assist with distance learning through assistive technologyAI-powered devices like MyEye Pro use voice-activated, intuitive AI to audibly describe what's in a room, respond to open-ended queries for specific information, and help users recognize faces.
- *Wearable Technology*: Smart glasses and head-mounted displays are becoming increasingly sophisticated, offering hands-free magnification and real-time text-to-speech capabilities.
- *Enhanced Connectivity*: Modern devices feature improved wireless connectivity, allowing seamless integration with classroom technology and remote learning platforms.
- *Augmented Reality*: AR capabilities are being integrated into magnification devices to provide contextual information and enhanced visual overlays.

Table 6.1: Comparison of video magnification devices: model, deployment, and company (2025 Update)

Model	Deployment	Company
AceSight VR	VR Headset	Zoomax
Acesight	E-Glasses	Zoomax
Acesight 8	E-Glasses	Zoomax
Acuity 22	Desktop	Irie AT
Acuity 22 Speech	Desktop	Irie AT
Amigo	Portable	Enhanced Vision
Clearview+ HD 22"	Desktop	Enhanced Vision

Continued on next page

Table 6.1: Comparison of video magnification devices: model, deployment, and company (2025 Update) (Continued)

Model	Deployment	Company
Cloverbook Plus	Mobile	Irie-AT
Cloverbook Pro	Mobile	Irie-AT
Connect 12	Desktop, Mobile	Humanware
explorē 12	Portable	Humanware
JAWS Picture Smart AI	Software/AI Enhancement	Freedom Scientific
Luna HD 24 Pro	Desktop (24” widescreen)	Zoomax
MyEye Pro	Wearable/AI-Powered	OrCam
OrCam Read 3	Portable/AI Reading	OrCam
Reveal 16i	Desktop	Humanware
ZoomText 2025	Software Magnifier	Freedom Scientific

Table 6.2: Comprehensive video magnification devices and screen magnifiers for visually impaired students (2025 Update)

Model	Deployment/Screen	Company
AceSight VR	VR Headset	Zoomax
Acesight	E-Glasses	Zoomax
Acesight 8	E-Glasses	Zoomax
Clearview+ HD 22”	Desktop (22” HD)	Enhanced Vision
Connect 12 (10x)	Desktop, Mobile	Humanware

Continued on next page

Table 6.2: Comprehensive video magnification devices and screen magnifiers for visually impaired students (2025 Update) (Continued)

Model	Deployment/Screen	Company
Connect 12 (25x)	Desktop, Mobile	Humanware
Distance Camera	Hand-Held	Zoomax
explorē 5	Hand-Held (5” screen)	Humanware
explorē 8	Hand-Held (8” screen)	Humanware
explorē 12	Hand-Held (12” screen)	Humanware
I-See 22”	Desktop	Irie AT
JAWS Picture Smart AI	Software/AI Enhancement	Freedom Scientific
Juno	Hand-Held (7” screen)	APH
Jupiter Portable Magnifier	Desktop, Mobile (heavy)	APH
Luna 6	Hand-Held (6” screen)	Zoomax
Luna 8	Hand-Held (8” screen)	Zoomax
Luna Eye	Hand-Held	Zoomax
Luna HD 24 Pro	Desktop (24” widescreen)	Zoomax
Luna HD Pro	Desktop	Zoomax
Luna S	Hand-Held (4.3” screen)	Zoomax
MAGNA 3	Hand-Held (3.5” screen)	Orbit Research
MAGNA 4	Hand-Held (4.3” screen)	Orbit Research
MAGNA 5	Hand-Held (5” screen)	Orbit Research
MATT Connect v2	Desktop, Mobile (heavy)	APH

Continued on next page

Table 6.2: Comprehensive video magnification devices and screen magnifiers for visually impaired students (2025 Update) (Continued)

Model	Deployment/Screen	Company
Magnibot	Desktop, Mobile	Trysight
MagniLink Air	Desktop	Low Vision International
MagniLink Tab	Desktop	Low Vision International
MagniLink One	Desktop	Low Vision International
MagniLink S Premium	Mobile	Low Vision International
MagniLink Vision	Desktop	Low Vision International
MagniLink WifiCam	Mobile	Low Vision International
MagniLink Zip	Desktop	Low Vision International
Merlin Mini	Mobile	Enhanced Vision
MyEye Pro	Wearable/AI-Powered	OrCam
ONYX Desk set HD	Desktop	Freedom Scientific
ONYX OCR	Desktop	Freedom Scientific
OrCam Read 3	Portable/AI Reading	OrCam
Panda HD	Desktop	Zoomax
Pebble HD	Handheld	Enhanced Vision
RUBY	Hand-Held (4.3” screen)	Freedom Scientific
RUBY 10	Hand-Held (10” Screen)	Freedom Scientific
RUBY 7 HD	Hand-Held (7” Screen)	Freedom Scientific
RUBY HD	Hand-Held (4.3” screen)	Freedom Scientific

Continued on next page

Table 6.2: Comprehensive video magnification devices and screen magnifiers for visually impaired students (2025 Update) (Continued)

Model	Deployment/Screen	Company
RUBY XL HD	Hand-Held (5” screen)	Freedom Scientific
Reveal 16	Desktop	Humanware
Reveal 16 (XY table)	Desktop	Humanware
Reveal 16i	Desktop	Humanware
Reveal 16i (XY table)	Desktop	Humanware
Snow 12	Desktop, Mobile	Zoomax
Snow Pad	Hand-Held	Zoomax
TOPAZ EZ HD	Desktop	Freedom Scientific
TOPAZ OCR	Desktop	Freedom Scientific
TOPAZ XL HD	Desktop	Freedom Scientific
Tactonum Pro	Desktop (Not Readily Mobile)	Tactonum
Tactonum Reader	Desktop (Not Readily Mobile)	Tactonum
Transformer HD	Mobile	Enhanced Vision
Traveller HD	Mobile	Optelec
ZoomText 2025	Software Magnifier/Reader	Freedom Scientific

6.1.1 Market Growth and Educational Impact

The assistive technology market for visually impaired students continues to expand rapidly. The global assistive technologies for visually impaired market size is expected to reach $12.31 billion by 2029 at 15% growth rate, segmented by educational devices and software, braille notetakers, screen readers, and accessible learning software. This growth reflects the increasing recognition of the importance of these technologies in educational settings and their proven effectiveness in supporting student success.

Educational institutions are increasingly investing in video magnification technology, supported by federal funding initiatives. The American Recovery Plan Act provides funds to libraries and schools to address student learning loss, close achievement gaps, and assist with distance learning through assistive technology, making these essential tools more accessible to students who need them.

The integration of artificial intelligence and machine learning capabilities in video magnification devices represents a significant advancement in accessibility technology. These features enable more intuitive interaction, automatic text recognition, and enhanced image processing, making the devices more effective tools for learning and independent living.

6.1.2 Considerations for Educational Settings

When selecting video magnification devices for educational environments, several additional factors should be considered:

- *Classroom Integration*: Devices should seamlessly integrate with existing classroom technology, including interactive whiteboards, projectors, and learning management systems.
- *Durability and Maintenance*: Educational settings require robust devices that can withstand frequent use by multiple students and require minimal maintenance.
- *Training and Support*: Comprehensive training programs for educators and ongoing technical support are essential for successful implementation.
- *Accessibility Standards*: Devices should comply with current accessibility standards and regulations, including Section 508 and WCAG guidelines.
- *Future-Proofing*: Given the rapid pace of technological advancement, devices should be updatable and compatible with emerging technologies.

The future of video magnification technology in education looks promising, with continued innovation in AI, augmented reality, and wearable technology promising to further enhance accessibility and learning outcomes for visually impaired students. As these technologies continue to evolve, they will play an increasingly vital role in ensuring that all students have equal access to educational opportunities and can achieve their full potential.

Part II

Accessibility Software Specs

Chapter 7

Transformative Tablets: Pioneering Success for Visually Impaired Students Through Innovative Apps

In an era where technology shapes the landscape of education, tablets have emerged as transformative tools, providing visually impaired students with unprecedented access to knowledge and fostering independence in their academic journeys.[1] Both iPad and Android devices offer user-friendly interfaces and a diverse array of applications specifically tailored to bridge the accessibility gap. This chapter explores how tablets, in tandem with purpose-built apps, are not just tools but catalysts for success in the educational journey of visually impaired students.

Tablets serve as dynamic portals for visually impaired learners, offering a multi-sensory approach to engagement. Their unique functionalities, combined with a robust ecosystem of accessibility apps, empower students to navigate the digital realm with confidence and independence.

7.1 Tablet Considerations

When selecting a tablet for students with visual impairments, consider the following:

[1] I am omitting iPhone and Android phones from this document as the purchase of student phones is beyond the purview of a school district. However, iOS apps are provided as many of these are available on both Tablets and Phones and training students to use the technology on their personal device is often necessary, particularly within the auspice of Orientation & Mobility instruction

- *Accessibility features:* Ensure compatibility with screen readers and magnification tools (e.g., VoiceOver for iOS, TalkBack for Android).[2]
- *Tactile features, size, and weight:* Choose a device that accommodates the student's specific needs.
- *Contrast and color settings:* High contrast and customizable color settings, as well as text-to-speech functionalities, enhance readability.
- *Screen size:* Larger screens can help reduce visual fatigue and improve usability, but balance with portability.
- *App compatibility:* Ensure the device supports a variety of educational and accessibility apps.
- *Visual fatigue:* Avoid prioritizing brightness; instead, focus on resolution and screen area. Adjust luminance for students with photophobia.
- *AI Integration:* Modern tablets now offer enhanced AI-powered accessibility features, including improved object recognition and natural language processing.

Contrast ratio is especially important for students with visual impairments. Understanding and prioritizing contrast ratio helps foster an inclusive and enriching educational environment.

7.2 Tablet Options

When choosing an Android Tablet or iPad for a student with visual impairments, several factors must be considered to ensure that the student receives free and appropriate public education. The first factor to consider is the screen contrast ratio. A high contrast ratio is essential for students with visual impairments as it makes it easier for them to read text and view images on the screen. For Android Tablets, the W3C recommends a contrast ratio of at least 4.5:1 for small text and 3.0:1 for large text[3]. Apple devices continue to excel with their "Increase Contrast" feature and additional accessibility enhancements[4].

The second factor to consider is the size of the screen. A larger screen is beneficial for students with visual impairments as it allows them to view text and images more clearly.

[2] Android accessibility features have significantly improved since 2020, with TalkBack now offering comparable functionality to VoiceOver. However, iOS devices still maintain a slight advantage in terms of app compatibility and developer support for accessibility features.

[3] Google. (n.d.). Color contrast - Android Accessibility Help. Retrieved December 19, 2023

[4] iMore. (n.d.). How to increase contrast for visual accessibility on iPhone and iPad. Retrieved December 19, 2023

Tablets usually have larger screens than smartphones, making them a better choice for students with visual impairments[5]. However, it is important to note that larger screens come at the expense of portability. Therefore, it is essential to find a balance between screen size and portability.

The third factor to consider is the availability of accessible apps. Both Android and iOS devices have built-in accessibility features such as screen readers, magnifiers, and high contrast modes [6,7]. Additionally, there are several apps available that are specifically designed for students with visual impairments. Enhanced AI-powered apps like Be My Eyes now include Be My AI functionality, while SeeingAI continues to evolve with improved object recognition capabilities[8].

Tables 7.1 through 7.4 describe current tablet computers that are available for students with visual impairments.

7.2.1 AndroidOS 14+ Tablets

Table 7.1: AndroidOS 14+ tablets suitable for students with visual impairments (Updated 2025)

Tablet	Screen Size
Google Pixel Tablet	10.9
Samsung Galaxy Tab A9	8.7
Samsung Galaxy Tab A9+	11.0
Samsung Galaxy Tab S9	11.0
Samsung Galaxy Tab S9 FE	10.9

Continued on next page

[5] American Foundation for the Blind. (n.d.). Smartphone or Tablet: Which is Best for You? Retrieved December 19, 2023

[6] American Academy of Ophthalmology. (n.d.). 30 Apps, Devices and Technologies for People With Vision Impairments. Retrieved December 19, 2023

[7] American Foundation for the Blind. (n.d.). Apple iOS for iPhone and iPad: Considerations for Users with Visual Impairments. Retrieved December 19, 2023

[8] American Academy of Ophthalmology. (n.d.). Technology Tools for Children with Low Vision. Retrieved December 19, 2023

Table 7.1: AndroidOS 14+ tablets suitable for students with visual impairments (Updated 2025) (Continued)

Tablet	Screen Size
Samsung Galaxy Tab S9 FE+	12.4
Samsung Galaxy Tab S9 Ultra	14.6
Samsung Galaxy Tab S9+	12.4
Samsung Galaxy Tab S10+	12.4
Samsung Galaxy Tab S10 Ultra	14.6
OnePlus Pad	11.6
OnePlus Pad 2	12.1
Lenovo Tab P12	12.7
Lenovo Tab P12 Pro	12.6
Lenovo Tab M10 Plus (4th Gen)	10.6
Lenovo Tab M11	11.0
Xiaomi Pad 6	11.0
Xiaomi Pad 6 Pro	11.0
Xiaomi Pad 6S Pro	12.4
Honor Pad 9	12.1
Realme Pad 2	11.5
Redmi Pad Pro	12.1
Oppo Pad Air 2	11.4
Vivo Pad 3	12.1

Note: Summary: Comprehensive list of Android tablets running OS 14 or higher, showing model name and screen size in inches

7.2.2 iPadOS Tablets

Table 7.2: iPadOS tablets suitable for students with visual impairments (Updated 2025)

Tablet	Cost	Screen Size
Apple iPad 10.9 (10th Gen)	$349	10.9
Apple iPad Air 11 (M2)	$599	11.0
Apple iPad Air 13 (M2)	$799	13.0
Apple iPad Pro 11 (M4)	$999	11.0
Apple iPad Pro 13 (M4)	$1299	13.0
Apple iPad mini 7 (A17 Pro)	$499	8.3

7.2.3 Windows OS Tablets

Table 7.3: Windows OS tablets suitable for students with visual impairments (Updated 2025)

Tablet	Cost	Screen Size
Microsoft Surface Pro 11	$1199	13.0
Microsoft Surface Pro 10	$1099	13.0
Microsoft Surface Go 4	$629	10.5
Microsoft Surface Laptop Studio 2	$1999	14.4
Dell XPS 13 2-in-1	$1299	13.0
HP Spectre x360	$1149	13.5
Lenovo ThinkPad X1 Tablet	$1449	13.0

Continued on next page

Table 7.3: Windows OS tablets suitable for students with visual impairments (Updated 2025) (Continued)

Tablet	Cost	Screen Size
Asus VivoBook 13 Slate	$849	13.3

7.2.4 ChromeOS Tablets

Table 7.4: ChromeOS tablets suitable for students with visual impairments (Updated 2025)

Tablet	Cost	Screen Size
Lenovo Chromebook Duet 3	$349	11.0
Lenovo Chromebook Duet 5	$449	13.3
HP Chromebook x2 11	$599	11.0
Asus Chromebook CM3	$399	10.5
Acer Chromebook Spin 714	$729	14.0

7.3 Mobile Applications

Mobile apps run on tablets are becoming increasingly important for students with visual impairments to access a free and appropriate public education. These apps can provide students with access to digital content, assistive technology, and other tools that can help them succeed in their studies. High-quality mobile apps can help students with visual impairments access the same educational materials as their sighted peers and participate fully in the curriculum. They can also help improve literacy skills, comprehension, and productivity. In this section, we will explore the importance of high-quality mobile apps for students with visual impairments and discuss some of the best apps available on the market today.

Accessibility Training/Auditory Games

Table 7.5: Mobile apps for accessibility training and auditory games for students with visual impairments (Updated 2025)

App	Cost	Function	OS
CosmoBally in Space	free	Train VoiceOver Gestures	iOS/iPadOS
Ballyland Magic Plus	$4.99	Train VoiceOver Gestures	iOS/iPadOS
Ballyland Rotor	$3.99	Train VoiceOver rotor	iOS/iPadOS
Ballyland Stay Still Squeaky!	$3.99	Train VoiceOver Gestures	iOS/iPadOS
Blindfold Games Launcher	free[12]	Sonic Games	iOS/iPadOS
Blindfold Tap and Swipe	free	Train VoiceOver Gestures	iOS/iPadOS
ObjectiveEd Games	free[12]	Sonic Games	iOS/iPadOS
VO Lab	$5.99	Train VoiceOver Gestures	iOS/iPadOS
Screenreader	free	Train Accessibility Gestures	iOS/iPadOS, Android 14+

7.3.1 Cortical Vision Impairment

Table 7.6: Mobile apps for cortical vision impairment (CVI) training for students with visual impairments (Updated 2025)

App	Cost	Function	OS
Art of Glow	free	CVI-based Vision Training	iOS/iPadOS
Big Band Patterns	$39.99	CVI-based Vision Training	iOS/iPadOS
Big Bang Pictures	$39.99	CVI-based Vision Training	iOS/iPadOS
CVI Connect	$12/mo	CVI-based Vision Training	iOS/iPadOS
CVI Connect Pro	free[16]	CVI-based Vision Training	iOS/iPadOS
CVI Toddler Visual Eye Train	free	CVI-based Vision Training	iOS/iPadOS
CVI Training (Color)	free	CVI-based Vision Training	iOS/iPadOS
CVI Training (Human face)	free	CVI-based Vision Training	iOS/iPadOS
CVI Training (Pattern)	free	CVI-based Vision Training	iOS/iPadOS
CVI Training (Recognition)	free	CVI-based Vision Training	iOS/iPadOS
CVI Training (Visual Tracking)	free	CVI-based Vision Training	iOS/iPadOS

Continued on next page

Table 7.6: Mobile apps for cortical vision impairment (CVI) training for students with visual impairments (Updated 2025) (Continued)

App	Cost	Function	OS
Dexteria VMI	$6.99	CVI-based Vision Training	iOS/iPadOS
EDA Play	$5.99	CVI-based Vision Training	iOS/iPadOS
EDA Play ELIS	$3.99	CVI-based Vision Training	iOS/iPadOS
EDA Play PAULI	$3.99	CVI-based Vision Training	iOS/iPadOS
EDA Play TOBY	free	CVI-based Vision Training	iOS/iPadOS
EDA Play TOM	free	CVI-based Vision Training	iOS/iPadOS
EyeMove	free	CVI-based Vision Training	iOS/iPadOS
Little Bear Sees	$5.99	CVI-based Vision Training	iOS/iPadOS
Peekaboo Barn	$3.99	CVI-based Vision Training	iOS/iPadOS
Sensory Light Box	$4.99	CVI-based Vision Training	iOS/iPadOS
Tap-n-See Now	$3.99	CVI-based Vision Training	iOS/iPadOS
Visual Attention Therapy Lite	free	CVI-based Vision Training	iOS/iPadOS

Note: Summary: Specialized apps designed for CVI training and assessment, including current pricing and supported platforms

7.3.2 Audiobook/Reading

Table 7.7: Mobile apps for audiobook, e-book, and DAISY reading for students with visual impairments (Updated 2025)

App	Cost	Function	OS
Audible	free[35]	Audiobook	iOS/iPadOS, AndroidOS 14+
BARD Mobile	free[36]	e-Book	iOS/iPadOS, AndroidOS 14+
Bookshare Reader	free	DAISY Reader	iOS/iPadOS
Dolphin EasyReader	free	DAISY Reader	iOS/iPadOS, AndroidOS 14+
KNFB Reader (OneStepReader)	$109.99	OCR/Reading	iOS/iPadOS, AndroidOS 14+
Kindle	free[37]	e-Book	iOS/iPadOS, AndroidOS 14+
Libby	free[38]	Audiobook	iOS/iPadOS, AndroidOS 14+
Speech Central	free[39]	Text-to-Speech	iOS/iPadOS, AndroidOS 14+
VoiceDream Reader	$19.99[40]	DAISY Reader	iOS/iPadOS

Productivity/Schoolwork/Optical Character Recognition

Table 7.8: Mobile apps for productivity, schoolwork, and optical character recognition (OCR) for students with visual impairments (Updated 2025)

App	Cost	Function	OS
Aiko	free	AI Speech to text	iOS/iPadOS

Continued on next page

Table 7.8: Mobile apps for productivity, schoolwork, and optical character recognition (OCR) for students with visual impairments (Updated 2025) (Continued)

App	Cost	Function	OS
Ballyland Code 1: Say Hello	$3.99	Auditory Coding	iOS/iPadOS
Ballyland Code 2: Give Rotor	$3.99	Auditory Coding	iOS/iPadOS
Ballyland Code 3: Pick Up	$3.99	Auditory Coding	iOS/iPadOS
Clusiv	free[53]	Online learning platform	iOS/iPadOS
Code Quest	free	Auditory Coding	iOS/iPadOS
Desmos Graphing Calculator	free	Accessible Graphing	iOS/iPadOS, AndroidOS 14+
Desmos Scientific Calculator	free	Accessible Scientific Calculator	iOS/iPadOS, AndroidOS 14+
Envision AI	free[54]	AI-powered OCR	iOS/iPadOS, AndroidOS 14+
GoodNotes 5	$7.99	Scan & Markup Documents	iOS/iPadOS, AndroidOS 14+
Microsoft 365	free[55]	Office Suite	iOS/iPadOS, AndroidOS 14+
Notability	$11.99	Scan & Markup Documents	iOS/iPadOS
SeeingAI	free	Talking Camera	iOS/iPadOS, AndroidOS 14+

Continued on next page

Table 7.8: Mobile apps for productivity, schoolwork, and optical character recognition (OCR) for students with visual impairments (Updated 2025) (Continued)

App	Cost	Function	OS
TapTapSee	free	Talking Camera	iOS/iPadOS, AndroidOS 14+
Voice Control for ChatGPT	free[56]	AI Assistant	iOS/iPadOS, AndroidOS 14+

Orientation & Mobility / Navigation

Table 7.9: Mobile apps for orientation, mobility, and navigation for students with visual impairments (Updated 2025)

App	Cost	Function	OS
Apple Maps	free	Turn by Turn Navigation	iOS/iPadOS
Be My Eyes	free	Visual assistance via volunteers	iOS/iPadOS, AndroidOS 14+
BlindSquare	$49.99	GPS Navigation	iOS/iPadOS
Clew	free	Indoor navigation	iOS/iPadOS, AndroidOS 14+
GoodMaps Explore	free	Indoor/Outdoor navigation	iOS/iPadOS
Google Maps	free	Turn by Turn Navigation	iOS/iPadOS, AndroidOS 14+
Lazarillo	free	GPS navigation	iOS/iPadOS, AndroidOS 14+
Moovit	free[60]	Public Transit	iOS/iPadOS, AndroidOS 14+

Continued on next page

Table 7.9: Mobile apps for orientation, mobility, and navigation for students with visual impairments (Updated 2025) (Continued)

App	Cost	Function	OS
Oko	free	Smart traffic detection	iOS/iPadOS, AndroidOS 14+
Soundscape	free	3D audio navigation	iOS/iPadOS, AndroidOS 14+
Waymap	free	Indoor/Outdoor navigation	iOS/iPadOS, AndroidOS 14+

7.3.3 Independent Living Skills

Table 7.10: Mobile apps for independent living skills for students with visual impairments (Updated 2025)

App	Cost	Function	OS
CashReader	free[70]	Currency identification	iOS/iPadOS, AndroidOS 14+
Lookout	free	AI-powered assistance	AndroidOS 14+
Magnifier	free	Built-in magnification	iOS/iPadOS
Menus4All	free[71]	Restaurant menus	iOS/iPadOS
PenFriend	free	Labeling system app	iOS/iPadOS
Supersense	free[72]	AI scene description	iOS/iPadOS, AndroidOS 14+

Continued on next page

Table 7.10: Mobile apps for independent living skills for students with visual impairments (Updated 2025) (Continued)

App	Cost	Function	OS
Voice Assistant	free	Voice control	iOS/iPadOS, AndroidOS 14+

7.4 Conclusion

The landscape of assistive technology for visually impaired students continues to evolve rapidly, with new applications and enhanced features being released regularly. When selecting tablets and applications for educational use, it is essential to consider the specific needs of each student, the available budget, and the compatibility with existing assistive technologies. Regular updates to both hardware and software ensure that students have access to the most current and effective tools for their educational success.

The integration of artificial intelligence and machine learning in accessibility applications has significantly improved the user experience for visually impaired students. From enhanced object recognition to more accurate optical character recognition, these technological advances continue to break down barriers and provide greater independence in educational settings.

Chapter 8

Beyond Boundaries: Text-to-Speech and DAISY as Catalysts for Literacy and Success in Visual Impairment Education

The National Instructional Materials Accessibility Standard (NIMAS) and Digital Accessible Information System (DAISY) are two important tools for the education of students with visual impairments. NIMAS is a technical standard used by publishers to prepare electronic files that are used to convert instructional materials into accessible formats. The purpose of NIMAS is to help increase the availability and timely delivery of instructional materials in accessible formats for qualifying students in elementary and secondary schools, with the National Instructional Materials Access Center (NIMAC) serving as a federally funded, online file repository of more than 83,000 K-12 NIMAS files[1]. DAISY is a digital format for audio books that is designed to be more accessible to people with visual impairments, with files that can be used to produce formats like braille, EPUB, DAISY, and large print[2].

Under IDEA, students must be receiving special education services under IDEA and meet the qualification criteria of the National Library Service for the Blind and Print Disabled (NLS) statute to be eligible for NIMAS-derived materials through the NIMAC[3].

---

1 NIMAC. (2025). National Instructional Materials Access Center. Retrieved July 4, 2025

2 DAISY Consortium. (2024). What is DAISY? Retrieved July 4, 2025

3 Connecticut State Department of Education. (2025). Accessible Educational Materials. Retrieved July 4, 2025

NIMAS and DAISY are important because they help make educational materials more accessible to students with visual impairments. By providing instructional materials in accessible formats, students with visual impairments can participate more fully in the general education curriculum. This can help improve their academic performance and increase their chances of success in school.

Finally, NIMAS and DAISY can help students with visual impairments become more independent. By providing instructional materials in accessible formats, students can read books, take notes, and communicate with others more easily. This can help them lead more fulfilling lives and become more active members of their communities.

In the evolving landscape of education, the pursuit of literacy is a journey marked by innovation and inclusivity. For visually impaired students, the traditional pathways to literacy take on a distinctive form, guided by the transformative power of audiobook and DAISY readers. This chapter explores the indispensable role that these tools play in breaking down barriers to literacy, ensuring access to knowledge, and propelling visually impaired students towards academic success.

8.1 DAISY Readers

Assistive technology is a crucial tool for students with visual impairments or blindness to receive a free and appropriate public education. DAISY (Digital Accessible Information System) is a technical standard for digital audiobooks, periodicals, and computerized text that is designed to be a complete audio substitute for print material and is specifically designed for use by people with print disabilities, including blindness, impaired vision, and dyslexia[4].

Based on the MP3 and XML formats, the DAISY format has advanced features in addition to those of a traditional audiobook. Users can search, place bookmarks, precisely navigate line by line, and regulate the speaking speed without distortion[5]. DAISY also provides aurally accessible tables, references and additional information. As a result, DAISY allows visually impaired listeners to navigate something as complex as an encyclopedia or textbook, otherwise impossible using conventional audio recordings[6].

DAISY books provide full accessibility for the reader and allow the reader to play the book on a variety of hardware and software players depending on the DAISY file type (e.g., CD players, mobile phones, computers, iPods & iPads, tablets, etc.)[7].

4 Wikipedia. (2024). Digital Accessible Information System. Retrieved July 4, 2025
5 Ibid.
6 Encyclopedia MDPI. (2022). DAISY Digital Talking Book. Retrieved July 4, 2025
7 California Department of Education. (2025). Digital Talking Books. Retrieved July 4, 2025

Table 8.1: DAISY readers and digital audio players: models, function, and company (Updated 2025)

Model	Function	Company
Milestone 212 Ace Book Reader	DAISY Reader, Digital Audio Player	Bones
PlexTalk PTN2	DAISY Reader, CD Player	PlexTalk
PlexTalk Pocket	DAISY Reader, Digital Audio Player	PlexTalk
Reizen DAISY Digital Recorder	DAISY Reader, Digital Audio Player	Reizen
Victor Reader Stratus	DAISY Reader, Digital Audio Player (Desktop)	Humanware
Victor Reader Stream	Digital Audio Player	Humanware
Victor Reader Trek	GPS, Digital Audio Player	Humanware
Victor Reader Stratus 12	Advanced DAISY Reader, Digital Audio Player	Humanware

8.2 Text-to-Speech

The use of assistive technology, including Text-to-Speech, is required for all students with disabilities that show a need under the Individuals with Disabilities Education Act (IDEA), with eligibility criteria including those with visual impairments, perceptual disabilities, or those otherwise unable through physical disability to hold or manipulate a book or to focus or move the eyes to the extent that would be normally acceptable for reading[8].

With the push of a single button, text to speech devices photograph your reading material and within seconds, begin reading it aloud. These easy-to-use devices are ideal for blind users of all ages and abilities. Some devices offer the option of smart reading features that enable you to simply ask for the text that interests you and some even offer facial and

[8] National Center on Accessible Digital Educational Materials. (2024). Addressing Accessible Educational Materials in the 2024 Assistive Technology Guidance. Retrieved July 4, 2025

product recognition[9].

Table 8.2: Text-to-speech devices: model, function, and company (Updated 2025)

Model	Function	Company
C-Pen Reader	Pen Scanner, Text-to-Speech Reader	C-Pen
OrCam MyEye Pro	AI-powered Smart Glasses, Text-to-Speech, Object Recognition	OrCam
OrCam Read 3	Hand-held Text-to-Speech Reader	OrCam
Scanmarker Air	Hand-held Text-to-Speech Scanner	Scanmarker
Enhanced Vision Smart Reader HD	Portable Text-to-Speech Reader	Enhanced Vision
Voice Dream Reader	Software-based Text-to-Speech (iOS/Android)	Voice Dream
KNFB Reader	Mobile App Text-to-Speech	KNFB
Speechify	AI-powered Text-to-Speech Software	Speechify

8.3 Emerging Technologies and Future Directions

The landscape of assistive technology for visual impairment education continues to evolve rapidly. Assistive technology for people with disabilities has come a long way, with 2025 bringing new tools that are improving their lives[10].

Advanced text-to-speech tools and voice cloning technology are bringing new levels of

[9] VisionAid. (2025). Text-to-speech. Retrieved July 4, 2025

[10] Speechify. (2025). 10 assistive technology tools to help people with disabilities in 2025 and beyond. Retrieved July 4, 2025

inclusivity to visually impaired people and individuals with speech disorders[11].

Modern text-to-speech technology has advanced significantly, offering more natural-sounding voices, better pronunciation of technical terms, and improved navigation features. These advancements make educational materials more accessible and engaging for students with visual impairments.

8.4 Implementation and Best Practices

Educational institutions must ensure proper implementation of these technologies to maximize their effectiveness. The Department of Education provides guidance to states, state educational agencies (SEAs), local educational agencies, and other interested parties with information to facilitate implementation of the National Instructional Materials Accessibility Standard and coordination with the National Instructional Materials Access Center[12].

Key considerations for implementation include:

- Early identification and assessment of students who would benefit from these technologies
- Proper training for educators and support staff on the use of DAISY and text-to-speech devices
- Regular evaluation and updating of assistive technology resources
- Collaboration between special education professionals, general education teachers, and technology specialists
- Ensuring compatibility between different systems and formats

8.5 Conclusion

The integration of NIMAS, DAISY, and text-to-speech technologies represents a significant advancement in educational accessibility for students with visual impairments. These tools not only provide access to educational materials but also promote

[11] Respeecher. (2024). How to Empower the Visually Impaired with Advanced Text-to-Speech Tools. Retrieved July 4, 2025

[12] U.S. Department of Education. (2021). Questions and Answers on the National Instructional Materials Accessibility Standard (NIMAS). Retrieved July 4, 2025

independence, enhance learning outcomes, and prepare students for success in academic and professional environments.

The DAISY Consortium continues to work with over 150 partners all around the world to improve access to reading for people with print disabilities[13], demonstrating the ongoing commitment to advancing these technologies.

As technology continues to evolve, the future holds even greater promise for breaking down barriers to literacy and ensuring that all students, regardless of their visual abilities, have equal access to educational opportunities. The continued development and implementation of these assistive technologies will play a crucial role in creating truly inclusive educational environments.

[13] DAISY Consortium. (2024). Home - The DAISY Consortium. Retrieved July 4, 2025

Chapter 9

Navigating Independence: The Essential Role of Accessible Daily Living Technology in Empowering Visually Impaired Students for Success and Safety

In the pursuit of independence and safety, orientation and mobility training holds a pivotal place in the educational journey of visually impaired students. In this dynamic landscape, accessible GPS equipment emerges as a technological beacon, offering a transformative bridge to mobility, autonomy, and enhanced safety. This chapter explores the indispensable role that accessible GPS tools play in empowering visually impaired students for success, ensuring safe navigation through the world, and fostering a sense of confidence in their daily lives.

The quest for independence is intricately tied to the ability to navigate and explore the surrounding environment. For visually impaired students, this journey is often met with challenges that extend beyond the typical obstacles encountered in education. Accessible GPS equipment becomes a critical ally, providing not only the means to explore the world independently but also enhancing safety through reliable navigational assistance.

As we delve into this chapter, we will explore the functionalities of accessible GPS devices tailored to the unique needs of visually impaired users. From real-time audible directions to haptic feedback systems, these tools extend beyond standard navigation, creating a multi-sensory experience that empowers students to traverse their surroundings confidently. The importance of this technology is accentuated during orientation and mobility training, where students learn not only to navigate physical spaces but also to develop crucial skills for safety and situational awareness.

Beyond the practicalities of navigation, the impact of accessible GPS equipment on student success cannot be overstated. These tools contribute to broader educational goals by fostering a sense of independence, reducing reliance on external assistance, and instilling a foundational skill set for safe and self-assured mobility.

Through this exploration, it becomes clear that accessible GPS equipment is not merely a tool for navigation; it is a catalyst for empowerment and safety. Through orientation and mobility training, we ensure that visually impaired students can embark on their educational journeys with a sense of autonomy, confidence, and, above all, safety.

9.1 Accessible GPS Hardware and Software

When purchasing an accessible GPS unit for the blind, it is important to consider the following factors to ensure safe navigation and crossing of streets:

- *Audible signals*: The GPS unit should provide audible signals to indicate when it is safe to cross the street. This feature allows blind pedestrians to cross the road at the right time, more quickly and safely while maintaining their orientation throughout the crossing[1].
- *Compatibility*: The GPS unit should be compatible with other assistive technology devices, such as screen readers and braille displays[2].
- *Portability*: Portable GPS units are ideal for blind pedestrians who need to move around the city. They should be lightweight and easy to carry.
- *Battery life*: Battery life is an important consideration for portable GPS units. The battery should last long enough to get through a day without needing to be recharged.
- *Ease of use*: The GPS unit should be easy to use and adjust. It should have large buttons and controls that are easy to locate and operate.
- *AI integration*: Modern GPS systems now incorporate artificial intelligence to provide enhanced contextual guidance and real-time environmental awareness.

1 Inclusive City Maker. (n.d.). Pedestrian safety: Are your crossings safe for the visually impaired? Retrieved December 19, 2023

2 American Foundation for the Blind. (n.d.). Smartphone GPS navigation. Retrieved December 19, 2023

- *Indoor navigation*: Many current systems now support indoor navigation capabilities where traditional GPS signals are not available.

These considerations will help ensure that blind pedestrians have access to the tools they need to navigate and cross streets safely. *Table 9.1* lists current available accessible GPS hardware devices and applications.

Table 9.1: Accessible GPS hardware and software: model, function, and company

Model	Function	Company
Stellar Trek	GPS	Humanware
Victor Reader Trek	GPS + Digital Audio Player	Humanware
Wayband	GPS (Haptic Output)	WearWorks
Envision Glasses	AI-Powered GPS + Object Recognition	Envision
Glidance Glide	Self-Guided Mobility Assistant	Glidance
Audiom	Audio-Based Navigation	Audiom
BlindSquare	Smartphone GPS App	MIPsoft
Lazarillo	Free GPS Navigation App	Lazarillo
Nearby Explorer	GPS Navigation App	American Printing House
MyWay Classic	Comprehensive GPS App	Swiss Federation of the Blind
OKO AI Copilot	AI Traffic Signal Recognition	OKO
Voice Vista	3D Audio GPS (Microsoft)	Microsoft

9.2 Accessible Technology for Daily Living

Auditory feedback technology is essential for blind people to live independently and complete daily tasks. It provides a way for the visually impaired to interact with their environment and receive information that they would otherwise miss. Modern assistive technology has evolved significantly with the integration of artificial intelligence, providing more sophisticated and contextual assistance than ever before.

The integration of AI-powered assistance has revolutionized daily living technology for the visually impaired. These systems now offer on-demand guidance, contextual help, and enhanced environmental awareness through advanced algorithms and machine learning capabilities. For example, AI-powered tools can now provide real-time object recognition, text reading, and scene description, dramatically expanding the independence of visually impaired users.

Smart assistive navigation systems now combine voice-over technology with advanced object detection capabilities, offering guidance through auditory feedback and tactile input upon object recognition. These systems can identify people, animals, crosswalks, pavements, and uneven terrain, providing comprehensive environmental awareness that extends far beyond traditional mobility aids.

In addition to navigation, modern assistive technology supports learning and skill development. Recent advances in haptic feedback technology continue to enhance Braille learning, while AI-powered applications provide personalized learning experiences tailored to individual needs and preferences.

The global assistive technologies market for visually impaired individuals is projected to reach $12.31 billion by 2029, reflecting the growing recognition of these technologies' importance and the continued innovation in this field. This growth demonstrates the expanding availability and sophistication of tools designed to support independent living for the visually impaired community.

9.2.1 Accessible Home Technology

When purchasing household items modified to give audio feedback for the blind, it is important to consider the following factors to ensure that they can access activities of daily living[3]:

- *Audible feedback*: Household items should provide audible feedback to the user to ensure that they are being used correctly and safely.

[3] All About Vision. (n.d.). Adapting your home for better blindness accessibility. Retrieved December 19, 2023

- *Compatibility*: The item should be compatible with other assistive technology devices, such as screen readers and braille displays.
- *Ease of use*: The item should be easy to use and adjust. It should have large buttons and controls that are easy to locate and operate.
- *Portability*: Portable items are ideal for blind users who need to move around the house. They should be lightweight and easy to carry.
- *Cost*: The cost of the item should be reasonable and within the user's budget.
- *Smart home integration*: Modern devices should integrate with smart home systems and voice assistants for enhanced automation and control.
- *AI capabilities*: Advanced devices now incorporate artificial intelligence for improved functionality and personalized assistance.

These considerations will help ensure that blind users have access to the tools they need to perform activities of daily living safely and independently.

Table 9.2 shows a range of technology available for blind/visually impaired people designed to facilitate independent living[4].

Table 9.2: Accessible home technology: model and cost (Updated 2025)

Model	**Cost**
Infrared Talking Thermometer	$50
Liquid Level Indicator	$15
PenFriend Voice Labelling System	$190 (Extra 418 labels: $35)
Talking First Aid Guide	$40
Talking Indoor/Outdoor Thermometer	$20
Talking Kitchen Scale	$45
Talking Measuring Tape	$160

Continued on next page

[4] Prices updated from current market research and major vendors of products intended to facilitate independent living skills (2025)

Table 9.2: Accessible home technology: model and cost (Updated 2025) (Continued)

Model	Cost
Talking Meat Thermometer	$45
Talking Timer Clock	$20
Talking Watch	$25
Talking Weighing Scale	$45
Talking Pulse Oximeter	$40
Talking Scale (Body Weight)	$85
Talking Blood Pressure Monitor	$150
Talking Pill System	$85
Talking Blood Glucose Meter	$45
WayLink Scanner	$140 (Extra 25 magnets: $45)
Smart Talking Thermostat	$120
AI-Powered Voice Assistant Device	$80
Talking Color Identifier	$30
Smart Talking Doorbell	$150
Talking Barcode Scanner	$200
AI Reading Assistant (Mobile App)	$10/month
Smart Talking Smoke Detector	$75
Talking Currency Reader	$180

9.2.2 Emerging Technologies and Future Directions

The landscape of accessible technology continues to evolve rapidly, with several emerging technologies showing significant promise for enhancing independence and quality of life for visually impaired individuals:

- *AI-Powered Wearables*: Advanced smart glasses and wearable devices that provide real-time environmental description, object recognition, and contextual assistance through artificial intelligence.
- *Indoor Navigation Systems*: Sophisticated applications that enable safe navigation within buildings where GPS signals are unavailable, using smartphone sensors and specialized mapping data.
- *Haptic Feedback Devices*: Advanced tactile feedback systems that provide navigation guidance and environmental information through touch and vibration.
- *Voice-Activated Smart Home Integration*: Comprehensive home automation systems that respond to voice commands and provide audio feedback for all household functions.
- *Machine Learning Personalization*: Adaptive technologies that learn user preferences and behaviors to provide increasingly personalized assistance over time.

These emerging technologies represent the next frontier in accessible technology, offering unprecedented levels of independence and integration with everyday life. As these technologies continue to develop and become more affordable, they will play an increasingly important role in empowering visually impaired individuals to achieve their full potential in education, employment, and daily living.

Chapter 10

The Transformative Impact of AI and LLM Technologies on Accessibility for the Blind and Visually Impaired

10.1 Introduction

10.1.1 Overview of Visual Impairment and Accessibility Needs

Visual impairment presents a formidable global challenge, affecting more than 2.2 billion individuals worldwide. The profound personal hardships experienced by those with visual impairments are compounded by substantial societal costs, including significant lost productivity and considerable healthcare expenses. These factors collectively underscore an urgent and pressing need for innovative solutions aimed at enhancing accessibility and fostering greater autonomy for affected individuals.[1]

Historically, assistive technologies (AT) such as white canes and guide dogs have provided indispensable support, enabling many visually impaired individuals to navigate their environments and perform daily tasks. However, these traditional tools possess inherent limitations, often restricting the scope of independence and the richness of environmental interaction. This highlights a critical necessity for advanced technological interventions that can offer more comprehensive, dynamic, and nuanced assistance,

[1] Source: `https://arxiv.org/html/2503.15494v1`

moving beyond basic support to truly transformative empowerment.[2] The fundamental purpose of assistive technology is to empower individuals with visual impairments by supporting their daily functioning, facilitating access to educational opportunities, and delivering benefits that extend to both learning processes and social-emotional well-being.[3]

The sheer scale of visual impairment globally, coupled with its significant economic burden, establishes a compelling case for substantial investment and innovation in assistive technologies. The recognized limitations of traditional aids further emphasize that Artificial Intelligence (AI) and Large Language Model (LLM) solutions are not merely incremental improvements; rather, they represent potentially transformative shifts in empowering this population towards greater independence and more robust societal participation. If the problem is massive and current solutions are limited, there exists a profound unmet need. AI and LLMs are uniquely positioned to address this gap due to their advanced capabilities, transforming AI from a beneficial enhancement into a critical necessity for fostering a more inclusive society. The magnitude of the challenge demands transformative solutions, not just marginal ones.

10.1.2 The Rise of AI and LLMs in Assistive Technology

Artificial intelligence is proving profoundly transformative in addressing accessibility challenges, particularly for individuals with visual impairments. Recent advancements in machine learning and deep learning have enabled AI-powered systems to perform complex tasks with unprecedented accuracy and efficiency. These capabilities include real-time object recognition, sophisticated scene analysis, and natural language processing (NLP).[4]

The widespread proliferation of Generative AI (GenAI) tools has ushered in a critical shift in how individuals approach information retrieval and content creation across a diverse array of contexts. This includes significant applications in education, programming, communication, and creative work. Tools such as ChatGPT, Copilot, and Gemini have rapidly gained immense popularity due to their versatile capabilities.[5] Notably, existing accessibility technologies, including established platforms like Be My Eyes and Envision, have already begun to integrate GenAI capabilities. This integration specifically aims to assist blind users, particularly in the crucial area of answering visual questions by

[2] Source: `https://www.aimodels.fyi/papers/arxiv/ai-powered-assistive-technologies-visual-impairment`

[3] Source: `https://wjaets.com/sites/default/files/WJAETS-2024-0481.pdf`

[4] Source: `https://arxiv.org/html/2503.15494v1`

[5] Source: `https://maitraye.github.io/files/papers/BLV_GenAI_ASSETS24.pdf`

interpreting images and scenes.[6]

The integration of deep learning models, the development of multimodal interfaces, and the capability for real-time data processing have collectively transformed the functionality and usability of these assistive tools. This evolution has fostered enhanced inclusivity and empowerment for visually impaired individuals, providing them with more seamless and intuitive interactions with their environment and digital content.[7] The rapid integration of Generative AI into existing accessibility tools signifies a fundamental shift in approach, moving from simple assistive devices to intelligent, context-aware companions. This evolution is not merely about making existing tasks accessible; it fundamentally re-imagines the interaction between visually impaired individuals and their environment. It represents a progression towards proactive, comprehensive assistance rather than reactive, limited support. This combination of capabilities allows for more than just basic task completion; it enables a deeper understanding of surroundings, provides contextual information, and facilitates dynamic interaction. This moves beyond a mere ”tool” to a ”companion” that can interpret and proactively assist, fundamentally changing the user’s relationship with technology and their environment. It suggests a future where AI anticipates needs and provides seamless support, rather than solely responding to explicit commands.

10.2 AI and LLM Applications in Daily Living and Mobility

10.2.1 Enhancing Environmental Understanding

Object Recognition and Scene Description

AI-powered applications are revolutionizing how visually impaired individuals perceive and interact with their surroundings. Microsoft’s Seeing AI, for instance, extensively leverages computer vision and natural language processing (NLP) to identify objects, text, people, and scenes, providing rich audio descriptions that significantly deepen users’ understanding of their environment. This versatile application can read documents, identify products using barcodes, recognize faces and their associated emotions, and describe complex scenes and individual objects in real-time, offering immediate auditory information.[8]

---

6 Source: https://maitraye.github.io/files/papers/BLV_GenAI_ASSETS24.pdf
7 Source: https://arxiv.org/html/2503.15494v1
8 Source: https://arxiv.org/html/2503.15494v1; https://accessiblepharmacy.com/top-10-ai-tools-for-the-blind-and-visually-impaired/; https://blogs.microsoft.com/accessibility/seeing-ai/

Similarly, Envision Glasses represent a significant advancement in wearable assistive technology. These smart glasses integrate sophisticated cameras with real-time speech synthesis to deliver contextual information directly to the user, enabling more effective interaction with their surroundings. The accompanying Envision App, utilizing a smartphone's camera, can vocalize written information, describe scenes and objects, and even identify individuals nearby. Its proficiency in text and object recognition is notable, supporting over 60 languages, including the interpretation of handwritten notes.[9]

Be My AI, an advanced feature seamlessly integrated into the popular Be My Eyes application, is powered by OpenAI's GPT-4. This tool provides detailed AI-powered descriptions of images, serving as a robust and readily available alternative to human volunteers. Users can independently access visual information by simply capturing pictures of their environment, receiving comprehensive auditory feedback.[10] Another notable application, Lookout by Google, employs AI to assist individuals with low vision or blindness by providing spoken feedback regarding their surroundings, such as reading text or identifying objects, thereby directly aiding environmental comprehension.[11]

The SeeSay system represents a novel assistive device that leverages Large Language Models (LLMs) for both speech recognition and visual querying. It is designed to effectively identify, record, and respond to the user's environment by providing audio guidance through a methodology known as Retrieval-Augmented Generation (RAG). The system architecture comprises two primary components: a lightweight glasses attachment (housing a camera and ESP32 board) and a more powerful Raspberry Pi processing unit. SeeSay operates by running local LLMs, specifically Whisper for speech recognition, Phi-2 for query answering, and Piper TTS for speech synthesis, to deliver immediate audio feedback. For computationally intensive tasks, such as detailed image descriptions, the system intelligently offloads processing to cloud-based LLM services like ChatGPT. SeeSay is engineered to handle a wide range of inquiries, from straightforward questions to those requiring immediate environmental context or historical visual information, seamlessly escalating to cloud services when local LLM

9 Source: `https://arxiv.org/html/2503.15494v1`; `https://accessiblepharmacy.com/top-10-ai-tools-for-the-blind-and-visually-impaired/`; `https://www.letsenvision.com/`

10 Source: `https://accessiblepharmacy.com/top-10-ai-tools-for-the-blind-and-visually-impaired/`; `https://maitraye.github.io/files/papers/BLV_GenAI_ASSETS24.pdf`

11 Source: `https://accessiblepharmacy.com/top-10-ai-tools-for-the-blind-and-visually-impaired/`

responses are insufficient.[12]

The evolution of AI in environmental understanding for the visually impaired demonstrates a significant progression from basic object identification to comprehensive scene description and contextual understanding. This is often augmented by advanced techniques like Retrieval-Augmented Generation (RAG). This allows for not just the recognition of individual elements but a deeper comprehension of the entire environment, significantly boosting independence and confidence in navigating complex spaces. The progression signifies that AI is moving beyond simply providing raw data to offering an interpreted, human-like understanding of the visual world. This directly translates to greater autonomy, as users can build a more complete mental model of their surroundings, reducing cognitive load and enhancing safety.

Navigation and Obstacle Detection

Independent mobility is a cornerstone of daily living, and AI is making profound strides in this area. NOA by biped.ai is a revolutionary live AI mobility companion, designed to be worn like a backpack. It serves as a sophisticated complement to traditional mobility tools such as white canes and guide dogs. This device integrates multiple cameras, a dedicated processing unit, and provides hands-free audio feedback via bone-conduction headphones, ensuring clear instructions while keeping the user's ears free for ambient sounds. NOA offers precise turn-by-turn GPS navigation, detects obstacles at various heights and distances both day and night through distinct auditory "beeps," and provides real-time AI descriptions of the surroundings, a feature referred to as "Live AI." Furthermore, it assists users in locating important objects like crosswalks and doors, functioning effectively in both indoor and outdoor environments.[13]

NaviLens represents another cutting-edge technology empowering blind and partially sighted individuals with enhanced navigation and information access. Its unique, colorful codes can be scanned from significantly greater distances compared to conventional QR or barcodes (up to 12 times farther, with a 10-inch code readable from 60 feet away). These codes can be read remarkably fast, in as little as 1/30th of a second, and support a wide-angle reading capability of up to 160 degrees, functioning reliably in all lighting conditions without requiring precise focus. NaviLens provides accurate distance and orientation information relative to the user and can detect multiple tags simultaneously,

[12] Source: https://www.themoonlight.io/en/review/seesay-an-assistive-device-for-the-visually-impaired-using-retrieval-augmented-generation; https://www.researchgate.net/publication/384700193_SeeSay_An_Assistive_Device_for_the_Visually_Impaired_Using_Retrieval_Augmented_Generation; https://arxiv.org/html/2410.03771v1

[13] Source: https://www.biped.ai/

efficiently communicating the relevant data. This technology is strategically deployed in various public spaces, including subway stations, bus stops, and museums, offering real-time information and facilitating indoor navigation without reliance on GPS or Bluetooth signals.[14]

For pedestrian safety, the Oko AI Copilot for the Blind is an iOS application that leverages the smartphone's camera to detect and announce the status of street crossings. It provides audible beeps and vibrations to alert users when it is safe or unsafe to cross, operating in a manner similar to talking pedestrian signals.[15] Additionally, the Sunu Band is a wearable device that employs ultrasonic sensors to detect obstacles in the user's immediate path, providing intuitive haptic feedback to guide them safely through their surroundings.[16]

The development of AI-powered navigation tools, ranging from wearable devices like NOA and Sunu Band to environmental tagging systems like NaviLens, signifies a crucial advancement towards truly independent mobility for visually impaired individuals. This progression moves beyond simple obstacle avoidance to a more comprehensive understanding of spatial relationships and contextual navigation. It integrates real-time environmental data with predictive guidance to enhance safety and confidence in dynamic environments. These tools collectively represent a shift from basic "alerting" to sophisticated "guiding" and "informing" in real-time. The integration of AI allows for the interpretation of complex visual scenes into actionable audio or haptic cues. This means visually impaired individuals can navigate unfamiliar and complex environments with unprecedented autonomy, reducing reliance on sighted assistance and fostering greater participation in public life. The focus is on creating a seamless, intuitive, and safe mobility experience.

10.2.2 Facilitating Information Access

Text and Document Reading

Natural Language Processing (NLP) plays a fundamental role in enabling access to digital information for visually impaired individuals. NLP-driven text-to-speech (TTS) systems are essential, converting written text into spoken words, thereby allowing users to access web content and other digital text that would otherwise be inaccessible. Conversely, speech-to-text (STT) systems perform the opposite function, converting spoken words

[14] Source: `https://www.navilens.com/`
[15] Source: `https://accessiblepharmacy.com/top-10-ai-tools-for-the-blind-and-visually-impaired/`
[16] Source: `https://arxiv.org/html/2503.15494v1`

into written text. Both technologies are particularly valuable for individuals with visual or hearing impairments, bridging critical communication gaps.[17]

Envision AI, available as both a smartphone application and integrated smart glasses, demonstrates exceptional proficiency in text recognition. It is capable of reading text in over 60 languages, including challenging formats such as handwritten notes, text on food packages, or entire books.[18] Microsoft's Seeing AI is another powerful tool, highly proficient at reading textbooks and various other documents, significantly enhancing the accessibility of educational and professional materials.[19]

Voice Dream Reader is a dedicated text-to-speech application that reads text from diverse sources, including PDFs, web pages, and electronic books. It supports multiple languages and offers a highly customizable reading experience, empowering students and professionals to access and comprehend a wide range of materials independently and according to their preferences.[20]

Picture Smart AI, developed by Freedom Scientific, the creators of the widely used JAWS screen reader, provides an AI-powered image description service specifically designed for computer users. This tool allows users to import existing photos or capture live screenshots of their computer screen to receive instant, detailed descriptions of on-screen elements. It leverages advanced AI models such as ChatGPT or Claude for its descriptive capabilities. This feature is also under development for integration with Zoom, enabling it to read and describe images shared during virtual meetings.[21]

Furthermore, the Restream Text to Audio Conversion service utilizes AI-powered speech-to-text transcription to accurately convert entire audio files into text documents. This functionality is highly beneficial for verifying spelling, noting specific details like phone numbers, or obtaining written descriptions of spoken visual content, thereby enhancing both productivity and accuracy in various professional and personal contexts.[22]

The evolution of text and document reading tools, from basic Optical Character Recognition (OCR) to sophisticated, multilingual, and context-aware systems, demonstrates AI's profound ability to bridge the information gap for visually impaired individuals. The integration of AI into traditional screen readers and the capability to

[17] Source: https://arxiv.org/html/2503.15494v1; https://www.numberanalytics.com/blog/ultimate-guide-nlp-accessibility

[18] Source: https://accessiblepharmacy.com/top-10-ai-tools-for-the-blind-and-visually-impaired/; https://www.letsenvision.com/

[19] Source: https://accessiblepharmacy.com/top-10-ai-tools-for-the-blind-and-visually-impaired/; https://blogs.microsoft.com/accessibility/seeing-ai/

[20] Source: https://victastudents.org.uk/ai-tools-for-blind/

[21] Source: https://accessiblepharmacy.com/top-10-ai-tools-for-the-blind-and-visually-impaired/

[22] Source: https://accessiblepharmacy.com/top-10-ai-tools-for-the-blind-and-visually-impaired/

process complex visual documents, such as screenshots of digital interfaces, signify a decisive move towards universal digital and physical information accessibility. This is critical for both daily life and professional tasks. This comprehensive approach ensures that visually impaired individuals can access, process, and interact with information from virtually any source—printed pages, digital screens, and spoken words—on par with sighted peers, fostering true information equity. This represents a significant step towards full participation in an increasingly information-dense world.

Conversational AI for Everyday Tasks

Generative AI tools, including prominent platforms like ChatGPT, Copilot, and Gemini, are extensively utilized by blind individuals for a wide array of content creation and information retrieval tasks. This adoption occurs despite recognized challenges such as accessibility issues within interfaces, occasional inaccuracies, and the phenomenon of "hallucinations" in their responses.[23]

Blind users leverage GenAI for diverse content creation activities, including summarizing, expanding, combining, rephrasing, and organizing existing materials such as resumes, articles, or meeting notes. These tools also prove invaluable for brainstorming new ideas, making their own content accessible to others, proofreading written work, and facilitating translation across languages. Some users even "chain" outputs, using one GenAI tool (e.g., Be My AI for image description) to generate input for another (e.g., ChatGPT for creating social media posts or stories).[24]

ChatGPT, with its enhanced voice and image recognition capabilities, now allows for continuous spoken interaction, enabling users to converse naturally with the AI. It can also provide written or auditory responses to images captured by a camera, offering context-sensitive help for visual queries.[25] Call Annie is another conversational chatbot designed for quick, voice-prompted interactions, serving as an always-available AI companion for users to ask questions and learn about various topics conversationally.[26]

Be My AI and newer Generative AI models like ChatGPT 4 are highly valued for their visual question answering capabilities. They provide rich and systematic descriptions of visual information that are often more detailed and comprehensive than those typically provided by sighted individuals, offering a new level of visual understanding.[27]

[23] Source: `https://maitraye.github.io/files/papers/BLV_GenAI_ASSETS24.pdf`
[24] Source: `https://maitraye.github.io/files/papers/BLV_GenAI_ASSETS24.pdf`
[25] Source: `https://accessiblepharmacy.com/top-10-ai-tools-for-the-blind-and-visually-impaired/`
[26] Source: `https://accessiblepharmacy.com/top-10-ai-tools-for-the-blind-and-visually-impaired/`
[27] Source: `https://maitraye.github.io/files/papers/BLV_GenAI_ASSETS24.pdf`

Conversational AI is fundamentally transforming passive information consumption into active, interactive engagement, enabling visually impaired individuals to not only retrieve information but also to create, refine, and adapt content. This fosters a new level of agency and intellectual independence, moving beyond mere access to active participation in the digital economy and creative pursuits. This signifies a shift from simply consuming information (e.g., listening to a screen reader) to actively producing and manipulating it. It allows visually impaired individuals to engage in tasks that require creative ideation, complex writing, and information synthesis, which were previously highly challenging or dependent on sighted assistance. This fosters self-reliance, opens professional opportunities, and enhances personal expression, representing true empowerment.

Table 10.1: Key AI/LLM Assistive Technologies for Daily Living

Technology Name	Primary Function	Key AI/LLM Component	Impact on Daily Living/Mobility
SeeSay	Environmental description, Visual querying	LLMs (Whisper, Phi-2, Piper TTS), RAG, Cloud LLMs (ChatGPT)	Provides real-time audio guidance, records surroundings for contextual responses, enhances confidence in unfamiliar environments.[67]
NOA by biped.ai	GPS navigation, Obstacle detection, AI description, Object finding	Computer Vision, AI (Live AI)	Offers hands-free turn-by-turn navigation, detects hazards day/night, describes surroundings in real-time, complements canes/guide dogs for enhanced mobility.[68]

Continued on next page

Table 10.1: Key AI/LLM Assistive Technologies for Daily Living (Continued)

Technology Name	Primary Function	Key AI/LLM Component	Impact on Daily Living/Mobility
Envision Glasses/App	Real-time text recognition, Scene description, Object identification, Hands-free video calling	Computer Vision, NLP, LLMs (ChatGPT integration)	Provides unobtrusive access to visual information, reads text in 60+ languages (including handwriting), describes objects/scenes, identifies people, and facilitates human assistance.[69]
NaviLens	Environmental information, Indoor/outdoor navigation	Computer Vision, Proprietary algorithms	Uses unique scannable codes for fast, wide-angle, long-distance reading without focus; provides precise distance/orientation; enhances independence in public spaces.[70]
Be My AI (Be My Eyes)	Detailed image description, Visual question answering	LLMs (GPT-4)	Offers 24/7 AI-powered visual descriptions from photos, reducing reliance on human volunteers for everyday visual tasks.[71]

Continued on next page

Table 10.1: Key AI/LLM Assistive Technologies for Daily Living (Continued)

Technology Name	Primary Function	Key AI/LLM Component	Impact on Daily Living/Mobility
Seeing AI (Microsoft)	Text reading, Object/Scene description, Face/Emotion recognition	Computer Vision, NLP	Narrates the world, reads documents, identifies products/people/scenes, providing real-time auditory information for daily tasks.[72]
Lookout by Google	Text reading, Object identification, Environmental feedback	AI (Computer Vision, NLP)	Provides spoken feedback about surroundings, helping users navigate and identify objects/text in their environment.[73]
Aira (Access AI)	Visual interpreting, Image/diagram description, Concept explanation	AI (Access AI), Human interpreters	Offers on-demand visual assistance from AI or human agents, explaining visual concepts and verifying AI accuracy.[74]

Continued on next page

Table 10.1: Key AI/LLM Assistive Technologies for Daily Living (Continued)

Technology Name	Primary Function	Key AI/LLM Component	Impact on Daily Living/Mobility
Picture Smart AI	Image description for computer screens/files	LLMs (ChatGPT, Claude)	Provides instant descriptions of on-screen icons and images, translates document pictures, aiding navigation of digital interfaces and online shopping.[75]
Oko AI Copilot	Street crossing status detection	AI (Computer Vision)	Uses smartphone camera to detect safe/unsafe crossing conditions, providing audible/vibratory alerts for enhanced pedestrian safety.[76]
ChatGPT Voice/Image	Conversational AI, Image analysis	LLMs, Voice Recognition, Image Recognition	Enables continuous spoken interaction, provides written/auditory responses to images with context-sensitive help for diverse queries.[77]

Continued on next page

Table 10.1: Key AI/LLM Assistive Technologies for Daily Living (Continued)

Technology Name	Primary Function	Key AI/LLM Component	Impact on Daily Living/Mobility
Call Annie	Conversational AI	LLMs, Voice Recognition	Offers quick, voice-prompted conversational interactions for information and learning, acting as an always-available AI friend.[78]
Sunu Band	Obstacle detection	Ultrasonic sensors, Haptic feedback	Wearable device providing haptic cues for detecting obstacles, enhancing safe navigation.[79]

This table provides a concise, comparative overview of the diverse AI and LLM assistive technologies discussed in the context of daily living and mobility. By presenting each technology alongside its primary function, key AI/LLM components, and direct impact, readers can quickly grasp the specific utility and underlying mechanisms of these innovations. This structured summary facilitates rapid comprehension and comparison, allowing for a clear understanding of how each tool contributes to enhancing independence and navigating the physical and informational world for visually impaired individuals. It serves as a valuable reference, condensing complex information into an easily digestible format.

10.3 AI and LLM in Education and Professional Environments

10.3.1 Transforming Learning Experiences

Accessible Educational Content

AI tools are profoundly improving the learning experience for blind and visually impaired learners by offering personalized assistance, fostering increased independence, and significantly enhancing the accessibility of educational content.[80]

NotebookLM, a tool developed by Google, exemplifies this transformation by converting class notes or any document into an engaging and easily comprehensible podcast-like conversation between two virtual speakers. This innovative tool explains information in a relaxed tone, often incorporating real-life examples, which is particularly advantageous for students who prefer auditory learning over traditional reading. As a free service, it is ideally suited for studying on the go, although its current compatibility is limited to PDF or TXT file formats.[81]

Be My AI provides detailed, AI-powered descriptions of images, directly assisting students in understanding visual content found in textbooks, diagrams, and other educational materials. Its 24/7 availability and support for follow-up questions allow for highly personalized assistance, enabling students to inquire about specific diagram details or conceptual clarifications.[82] Microsoft's Seeing AI further contributes to this by reading textbooks, identifying classroom objects, and describing images using AI, thereby making learning more accessible. For instance, a visually impaired student can leverage this tool to analyze trends in graphs, fostering greater participation in classroom activities.[83]

Voice Dream Reader is a versatile text-to-speech application that reads text from diverse sources, including PDFs, web pages, and electronic books. It supports multiple languages and offers a customizable reading experience, empowering students to access and comprehend a wide range of educational materials independently and according to their individual preferences.[84] Similarly, Envision AI, through its smartphone application and seamless integration with smart glasses, assists students in accessing printed materials, understanding their surroundings, and actively participating in classroom activities by reading text, describing scenes, and identifying objects and people. It features automatic

---

80 Source: `https://victastudents.org.uk/ai-tools-for-blind/`
81 Source: `https://victastudents.org.uk/ai-tools-for-blind/`
82 Source: `https://victastudents.org.uk/ai-tools-for-blind/`
83 Source: `https://victastudents.org.uk/ai-tools-for-blind/`
84 Source: `https://victastudents.org.uk/ai-tools-for-blind/`

language detection and reliably converts documents containing images into accessible text formats, even for languages other than English.[85]

The impact of AI on education for the visually impaired extends significantly beyond mere content access to fostering active participation and personalized learning. Tools that convert complex visual information, such as diagrams and graphs, into accessible auditory or tactile formats, coupled with conversational AI for interactive explanations, are creating an inclusive learning environment. In this environment, students can engage with complex concepts, develop critical thinking skills, and collaborate more effectively, thereby bridging traditional learning divides. These are not simply ”reading aids”; they are tools that enable comprehension and engagement. The ability to ”analyze trends in graphs”[86] or ask follow-up questions[87] means students are not just receiving information but actively processing and interacting with it. This leads to a more inclusive and equitable educational experience, where visually impaired students can participate more fully in classroom activities and pursue academic interests with greater independence, reducing the need for constant human intervention.

Personalized Learning Assistance

Generative AI tools are empowering blind participants to acquire new skills and enhance their proficiency in areas where they previously encountered significant challenges. Self-learners, in particular, find it immensely beneficial to receive immediate feedback and detailed explanations from GenAI when facing difficulties. This environment allows them to ask clarifying questions without any apprehension of judgment, fostering a safe and supportive learning space.[88]

Specific examples illustrate the breadth of this personalized learning assistance. One participant successfully learned songwriting with the aid of ChatGPT, demonstrating the AI’s capacity to support creative endeavors. Another individual gained simplified explanations of complex academic jargon, making challenging subjects more approachable. A third participant explored intricate mathematical concepts with greater ease. Notably, one participant reported acquiring more programming knowledge from ChatGPT in a single year than in the preceding two decades, as the AI effectively helped identify necessary functions and verify code snippets, accelerating their learning trajectory significantly.[89]

[85] Source: `https://victastudents.org.uk/ai-tools-for-blind/`
[86] Source: `https://victastudents.org.uk/ai-tools-for-blind/`
[87] Source: `https://victastudents.org.uk/ai-tools-for-blind/`
[88] Source: `https://maitraye.github.io/files/papers/BLV_GenAI_ASSETS24.pdf`
[89] Source: `https://maitraye.github.io/files/papers/BLV_GenAI_ASSETS24.pdf`

Access AI, seamlessly integrated into the Aira application, further enhances personalized learning. It can accurately describe images or diagrams and explain complex concepts in a manner that is easy to understand from a blind person's perspective. Moreover, users have the option to request verification of the AI's accuracy by a professional human interpreter, adding a crucial layer of reliability and trust to the personalized assistance provided.[90]

The personalized, non-judgmental, and always-available nature of AI-powered learning assistants, such as ChatGPT and Access AI, addresses a critical social-emotional and pedagogical aspect of education for visually impaired students. This empowers them to explore knowledge gaps, experiment with new concepts, and build confidence at their own pace. This effectively democratizes access to individualized tutoring and mentorship that might otherwise be unavailable or cost-prohibitive. Learning often involves trial-and-error and asking clarifying questions. For visually impaired individuals, this can be challenging if sighted support is limited, or if they feel self-conscious about perceived "basic" questions. AI removes these social barriers, providing a private, infinitely patient tutor. This fosters not just academic achievement but also self-efficacy and a growth mindset. It allows for truly customized learning paths, adapting to individual needs and pace, which is a significant leap towards equitable educational opportunities. The "always available" aspect[91] means learning is not constrained by human schedules or resources.

10.3.2 Empowering Professional Productivity

Workplace Tools and Digital Assistants

AI-powered workplace tools are fundamentally transforming professional productivity for visually impaired individuals. Copilot for Microsoft 365 exemplifies this by integrating AI directly into core productivity applications such as Word, Excel, and Outlook. This intelligent assistant automates repetitive tasks, assists in drafting emails, summarizes extensive data, and offers smart suggestions, significantly enhancing efficiency. This integration allows visually impaired professionals to work faster and smarter, substantially reducing their reliance on others for routine tasks.[92]

Microsoft Teams further contributes to an inclusive professional environment by offering built-in live transcription and captions. Powered by Azure Cognitive Services, these features make virtual meetings more accessible for individuals who are Deaf or hard of

---

[90] Source: https://victastudents.org.uk/ai-tools-for-blind/

[91] Source: https://accessiblepharmacy.com/top-10-ai-tools-for-the-blind-and-visually-impaired/

[92] Source: https://www.lexgillette.com/articles/paralympian-lex-gillettes-top-7-ai-tools-for-accessibility

hearing, and equally beneficial for those with visual impairments to follow discussions in real-time.[93] The "Read Aloud" feature, available across Outlook, Edge, and PowerPoint, converts visual content into accessible auditory information. This enables visually impaired users to hear emails, documents, and webpages read aloud, facilitating multitasking and improving comprehension in fast-paced work environments.[94]

Microsoft Translator is an invaluable tool for global communication, supporting speech-to-speech, text-to-speech, and image-based Optical Character Recognition (OCR) translation. This capability allows visually impaired professionals to connect seamlessly with international colleagues and audiences, effectively breaking down language barriers.[95] Furthermore, Read AI Meeting notes is an application designed to enhance productivity by joining virtual meetings (e.g., Zoom, Microsoft Teams, Google Meet) as a participant. It records the discussion and subsequently uses AI to generate a perfectly formatted summary document, typically within an hour. This tool can also summarize message conversations, such as lengthy email threads, significantly improving information retention and overall productivity.[96]

AI-powered workplace tools are moving beyond basic accessibility features, such as traditional screen readers, to actively augment productivity and enable visually impaired professionals to participate fully and independently in collaborative and information-intensive environments. This effectively levels the professional playing field by compensating for visual barriers in real-time, fostering greater independence, efficiency, and opportunities for career advancement. Professional work often involves complex tasks such as drafting, summarizing, real-time communication, and multilingual interaction. Traditional assistive technologies frequently required workarounds or human assistance for these functions. AI's role in augmentation means Copilot automates tasks and suggests content, making the user more efficient, not just able to access information. Live transcription in Teams ensures full participation in dynamic meetings. Read AI Meeting notes[97] addresses the challenge of capturing and summarizing spoken information, a critical professional skill. This signifies a shift from merely "accommodating" disability to actively "empowering" professionals. AI acts as a force multiplier, allowing visually impaired individuals to perform at higher levels, take on more complex roles, and compete more effectively in the modern workforce, reducing or

[93] Source: https://www.lexgillette.com/articles/paralympian-lex-gillettes-top-7-ai-tools-for-accessibility

[94] Source: https://www.lexgillette.com/articles/paralympian-lex-gillettes-top-7-ai-tools-for-accessibility

[95] Source: https://www.lexgillette.com/articles/paralympian-lex-gillettes-top-7-ai-tools-for-accessibility

[96] Source: https://accessiblepharmacy.com/top-10-ai-tools-for-the-blind-and-visually-impaired/

[97] Source: https://accessiblepharmacy.com/top-10-ai-tools-for-the-blind-and-visually-impaired/

eliminating the need for human intermediaries for many tasks.

Accessibility Feedback Analysis

The "Natural Language Processing (NLP) for Accessibility" initiative represents a strategic application of AI focused on enhancing digital accessibility. This project primarily utilizes NLP to analyze large volumes of social media interactions and bug reports. The core objective is to extract and synthesize actionable insights from user-generated content to improve accessibility features in software applications, with a particular focus on individuals with visual disabilities or eye conditions.[98]

Key objectives of this project include developing sophisticated NLP tools capable of automatically extracting and classifying accessibility-related feedback. This involves analyzing how software updates impact app accessibility over time by studying user reviews and feedback trends. Furthermore, the initiative aims to create advanced NLP-driven reporting tools that empower developers to rapidly identify common issues and emerging trends in accessibility. This systematic approach helps developers understand the broader ramifications of their modifications and enables more responsive and informed development practices, ensuring that accessibility is maintained or improved with each update.[99]

A critical aspect of this initiative is the integration of human expertise with automated NLP analysis. This involves collaborative efforts with accessibility experts and direct engagement with the visually impaired community. This participatory approach refines the accuracy and relevance of the NLP tools, ensuring that the developed solutions are not only technologically sound but also practically beneficial and genuinely responsive to the needs of users with disabilities.[100] Beyond structured feedback, NLP can also be leveraged to improve accessibility by analyzing user feedback through sentiment analysis, enabling organizations to understand the nuanced needs and concerns of users with disabilities, even when expressed indirectly.[101]

The application of NLP to systematically analyze accessibility feedback represents a crucial closed-loop system for continuous improvement in assistive technology design. By leveraging user-generated insights, this approach allows developers to proactively identify and address instances where AI systems "misfit" the needs of disabled users. This ensures that future AI solutions are truly human-centered and evolve responsively to the diverse and dynamic needs of the visually impaired community, thereby driving truly

98 Source: `https://wajdialjedaani.com/projects/project.html?id=project3`
99 Source: `https://wajdialjedaani.com/projects/project.html?id=project3`
100 Source: `https://wajdialjedaani.com/projects/project.html?id=project3`
101 Source: `https://www.numberanalytics.com/blog/ultimate-guide-nlp-accessibility`

inclusive innovation. This creates a virtuous cycle: AI helps identify problems with AI's accessibility, leading to better AI. It ensures that the development process is not static but continuously informed by the lived experiences of visually impaired users. This systematic feedback loop is critical for bridging the gap between design intent and actual user experience, leading to more robust, equitable, and truly inclusive AI solutions over time.

Table 10.2: AI and LLM Tools in Education and Work

Technology Name	Primary Application	Key AI/LLM Component	Impact on Education/Work
NotebookLM (Google)	Content transformation, Personalized learning	LLMs, Text-to-Speech	Transforms notes/documents into podcast-like conversations, making learning auditory and accessible on-the-go.[141]
Be My AI (Be My Eyes)	Image description, Visual question answering	LLMs (GPT-4)	Provides detailed descriptions of visual content in textbooks/materials, fostering independent learning and understanding.[142]
Access AI (Aira)	Image/diagram description, Concept explanation	AI, Human-in-the-loop verification	Explains visual concepts from a blind perspective, allows verification by professional interpreters, enhancing learning comprehension.[143]

Continued on next page

Table 10.2: AI and LLM Tools in Education and Work (Continued)

Technology Name	Primary Application	Key AI/LLM Component	Impact on Education/Work
Seeing AI (Microsoft)	Text reading, Object/Scene description	Computer Vision, NLP	Reads textbooks, identifies classroom objects/images, making educational content and environment accessible.[144]
Lookout by Google	Text reading, Object identification	AI	Provides spoken feedback for navigating learning environments, reading materials, and identifying classroom objects.[145]
Voice Dream Reader	Text-to-Speech, Document access	Text-to-Speech	Reads text from diverse sources (PDFs, web pages, books), supports multiple languages, and offers customizable reading experience for broad content access.[146]

Continued on next page

Table 10.2: AI and LLM Tools in Education and Work (Continued)

Technology Name	Primary Application	Key AI/LLM Component	Impact on Education/Work
Envision AI	Text reading, Scene description, Document conversion	Computer Vision, NLP	Helps access printed materials, understand surroundings, and converts documents with images into accessible text in multiple languages.[147]
Copilot for Microsoft 365	Workplace productivity, Digital assistant	LLMs	Automates tasks, drafts emails, summarizes data, and offers smart suggestions across Microsoft apps, enhancing professional efficiency.[148]
Microsoft Teams	Live transcription, Communication	Speech-to-Text (Azure Cognitive Services)	Provides real-time captions for meetings, making professional communication more inclusive.[149]
Read Aloud (Microsoft)	Document/Email/Webpage reading	Text-to-Speech	Converts visual content to auditory, facilitating multitasking and comprehension in fast-paced work environments.[150]

Continued on next page

Table 10.2: AI and LLM Tools in Education and Work (Continued)

Technology Name	Primary Application	Key AI/LLM Component	Impact on Education/Work
Microsoft Translator	Multilingual communication	Speech-to-Speech, Text-to-Speech, OCR	Breaks language barriers for global communication, enabling interaction with diverse international colleagues.[151]
Read AI Meeting notes	Meeting/Conversation summarization	AI (Speech-to-Text, NLP)	Joins virtual meetings to record and generate formatted summaries, enhancing information retention and productivity.[152]
NLP for Accessibility	Accessibility feedback analysis	NLP (Sentiment Analysis, Classification)	Analyzes user feedback and bug reports to identify accessibility issues, guiding developers for continuous improvement and inclusive design.[153]

This table provides a focused and structured overview of AI and LLM tools specifically tailored for educational and professional environments. By categorizing technologies by their primary application, key AI/LLM components, and direct impact on learning and work, it offers a clear and actionable summary for educators, employers, and visually impaired professionals. This format enables quick identification of relevant tools, highlights how AI is enhancing productivity and fostering inclusive learning, and serves as a valuable resource for strategic planning and implementation in these crucial domains.

10.4 AI and LLM in Recreation and Leisure

10.4.1 Accessible Gaming

The emergence of AI and LLM technologies is significantly expanding the accessibility of gaming for blind and low-vision (BLV) players, a domain traditionally challenging due to its heavy reliance on visual elements. GamerAstra, a generalized accessibility framework, exemplifies this advancement by leveraging a multi-agent AI design to facilitate access to video games that may lack native accessibility support. This framework integrates multi-modal techniques, including large language models (LLMs) and vision-language models (VLMs), to translate visual game experiences into rich, descriptive audio and textual narratives.[154]

GamerAstra's architecture includes specialized AI agents such as a Scene Parsing Agent, an Action Interpretation Agent, and a Narrative Generation Agent. These agents work concurrently to analyze game environments in real-time, describe detailed spatial and action-based information, and provide contextual guidance, akin to a helpful co-player. The system generates real-time audio cues for gaming feedback, enhances players' spatial sense, and assists with positional accuracy for interactions like targeting objects. It also supports various navigation and action execution methods, including keyboard arrow keys and hotkey actions, to accommodate different player preferences and degrees of visual impairment.[155] This signifies a breakthrough in making video games more inclusive by leveraging AI to translate visual game experiences into rich, descriptive audio and textual narratives, thereby dramatically improving gaming experiences.[156]

Beyond dedicated frameworks, accessible mobile games are also leveraging AI principles. Dice World, a collection of dice games, offers universally accessible tutorials and allows players to compete against AI characters or other players, with full VoiceOver accessibility and custom interfaces.[157] Frequency Missing is an audio story game that uses directional sounds to guide players, featuring full voice acting.[158] Audio Game Hub provides a collection of audio-based games, from disarming bombs to casino games, all played through sound with voice acting and sound effects.[159] Pitch Black, A Dusk Light

[154] Source: https://arxiv.org/abs/2506.22937; https://www.aimodels.fyi/papers/arxiv/gamerastra-enhancing-video-game-accessibility-blind-low; https://arxiv.org/html/2506.22937v1; https://www.researchgate.net/publication/374526766_Accessible_Play_Towards_Designing_a_Framework_for_Customizable_Accessibility_in_Games

[155] Source: https://arxiv.org/abs/2506.22937; https://arxiv.org/html/2506.22937v1

[156] Source: https://www.aimodels.fyi/papers/arxiv/gamerastra-enhancing-video-game-accessibility-blind-low

[157] Source: https://vi.ie/david-redmond-investigates-accessible-audio-games/

[158] Source: https://vi.ie/david-redmond-investigates-accessible-audio-games/

[159] Source: https://vi.ie/david-redmond-investigates-accessible-audio-games/

Story, is another audio story app that uses sound to guide movement, relying entirely on sound design for immersion.[160] These games demonstrate how AI-driven audio design and intelligent game mechanics can create immersive experiences without visual dependency.[161]

10.4.2 Creative Arts and Music

AI is democratizing creative expression for blind individuals, lowering traditional barriers in artistic and musical pursuits. For visual arts, AI tools are enabling new forms of art specifically designed for visually impaired individuals. Generative AI models, such as Generative Adversarial Networks (GANs) and image style algorithms, can enhance accessibility by generating detailed audio descriptions or tactile representations of visual art. A blind creative noted how AI has transformed their ability to detect colors accurately, understand patterns, and receive minute descriptions of videos and images, which has been invaluable for historical costume research and other visual analyses.[162] Adobe Firefly, an AI image generator, allows users to describe a desired image via text prompts, and the AI generates several options, empowering blind content creators to produce visual content through textual input.[163]

In music, AI is equally transformative. Google's Music AI Sandbox, powered by their Lyria 2 model, offers experimental tools developed in collaboration with musicians. This suite allows users to generate musical ideas simply by describing them in text prompts, overcoming physical limitations that might hinder playing traditional instruments or navigating complex digital audio workstations (DAWs).[164] For instance, users can request specific instruments or evoke moods and genres through language, translating creative visions into sound without complex physical interaction. The platform also allows for editing AI-generated music by transforming sections and adding new lyrical content, fostering unprecedented creative freedom.[165] One blind artist described how AI tools allow for uploading a video and receiving an audio description of it, enabling them to create audio-described music videos.[166] This integration of advanced AI models elevates existing assistive technologies, allowing AI to understand and interpret a wider range of

---

[160] Source: https://vi.ie/david-redmond-investigates-accessible-audio-games/
[161] Source: https://vi.ie/david-redmond-investigates-accessible-audio-games/
[162] Source: https://www.youtube.com/watch?v=PI71DRqcAtI&vl=id; https://pixel-gallery.co.uk/blogs/pixelated-stories/ai-art-for-the-visually-impaired
[163] Source: https://accessiblepharmacy.com/top-10-ai-tools-for-the-blind-and-visually-impaired/
[164] Source: https://assistivetechnologyblog.com/2025/05/google-music-ai-sandbox-accessibility-disabilities.html
[165] Source: https://assistivetechnologyblog.com/2025/05/google-music-ai-sandbox-accessibility-disabilities.html
[166] Source: https://www.youtube.com/watch?v=09YyhOkg8xg

inputs, generate more sophisticated musical outputs, and personalize the creative process.[167]

10.4.3 Sports and Physical Activities

AI and LLM technologies are making significant contributions to enhancing participation in sports and physical activities for visually impaired individuals, acting as a ”sighted guide” in many contexts.[168] The Touch2See system, developed by a French startup, is a revolutionary technological innovation that allows blind or partially sighted people to follow football matches and other sports in an immersive and autonomous way. This system uses a tablet that reproduces a miniature playing field, where a small magnetic disk moves in real-time to allow users to follow actions with their fingers. Variations in vibration intensity indicate the importance of game actions. Touch2See combines haptic feedback with audio descriptions, providing a dedicated commentator who narrates the match with extraordinary detail, including actions, atmosphere, and crowd reactions. This system leverages ultra-fast analysis of sports data via AI and 5G technology, ensuring immediate information updates with a latency of just 0.15 seconds.[169]

Microsoft’s Seeing AI, while primarily for daily living, also functions as a valuable tool in sports by helping users understand their surroundings, read signage, and identify objects in real-time, which can be crucial for navigating sports venues or understanding game environments.[170] Paralympian Lex Gillette utilizes various Microsoft AI tools, including Seeing AI and Copilot, to manage his daily life, training, and professional engagements, demonstrating how AI can open up experiences once inaccessible without human assistance.[171]

While not exclusively AI-driven, many adaptive sports and activities for the visually impaired incorporate technological adaptations that could be enhanced by AI. These include using sound-emitting balls for sports like soccer or bowling, and audio navigation tools for hiking. AI could further refine these by providing more precise auditory cues or

[167] Source: https://assistivetechnologyblog.com/2025/05/google-music-ai-sandbox-accessibility-disabilities.html
[168] Source: https://www.lexgillette.com/articles/paralympian-lex-gillettes-top-7-ai-tools-for-accessibility
[169] Source: https://www.embedded.com/touch2see-making-sports-accessible-to-blind-people/
[170] Source: https://www.lexgillette.com/articles/paralympian-lex-gillettes-top-7-ai-tools-for-accessibility
[171] Source: https://www.lexgillette.com/articles/paralympian-lex-gillettes-top-7-ai-tools-for-accessibility

real-time environmental descriptions, enhancing safety and participation.[172]

Table 10.3: AI and LLM Tools in Recreation and Leisure

Technology Name	Primary Application	Key AI/LLM Component	Impact on Recreation/Leisure
GamerAstra	Accessible video gaming	Multi-agent AI (LLMs, VLMs, Computer Vision)	Translates visual game experiences into rich audio/textual narratives, enables mental map building, real-time navigation, and supports diverse game genres for BLV players.[194]
Dice World, Frequency Missing, Audio Game Hub, Pitch Black	Mobile audio games	AI (for opponent logic), Audio design	Provides fully accessible gaming experiences through audio-based gameplay, voice acting, and directional sounds, fostering social interaction and entertainment.[195]

Continued on next page

[172] Source: https://www.brightfocus.org/resource/tips-for-playing-sports-with-low-vision/; https://www.iamhable.com/blogs/article/the-best-hobbies-for-the-visually-impaired-a-2025-guide-to-fun-fulfillment

Table 10.3: AI and LLM Tools in Recreation and Leisure (Continued)

Technology Name	Primary Application	Key AI/LLM Component	Impact on Recreation/Leisure
Google's Music AI Sandbox	Accessible music creation	LLMs (Lyria 2), Text-to-Music generation	Enables creation of musical ideas from text prompts, lowers barriers for musicians with physical/visual impairments, and allows for sophisticated editing.[196]
Adobe Firefly	Accessible image generation	Generative AI (Text-to-Image synthesis)	Empowers blind content creators to generate visual art from text descriptions, expanding creative possibilities.[197]
AI-powered image description (general)	Art appreciation, Visual research	Computer Vision, NLP	Provides detailed audio descriptions of visual art, images, and videos, enabling blind individuals to engage with and research visual content.[198]

Continued on next page

Table 10.3: AI and LLM Tools in Recreation and Leisure (Continued)

Technology Name	Primary Application	Key AI/LLM Component	Impact on Recreation/Leisure
Touch2See	Accessible live sports following	AI, 5G, Haptic feedback, Audio description	Allows blind/partially sighted individuals to follow football/other matches in real-time via tactile feedback and detailed audio narration, enhancing stadium experience.[199]
Seeing AI (in sports context)	Environmental understanding in sports	Computer Vision, NLP	Helps users understand surroundings, read signage, and identify objects in sports venues or during training, acting as a "sighted guide."[200]

This table offers a structured summary of AI and LLM tools that are specifically enhancing recreation and leisure activities for visually impaired individuals. It highlights how AI is making gaming more inclusive, democratizing creative arts and music production, and enabling greater participation in sports. By presenting these technologies and their impacts, the table serves as a quick reference for understanding the breadth of AI's influence in fostering a more active, engaging, and fulfilling lifestyle for the blind and visually impaired community.

10.5 Challenges and Ethical Considerations

While AI and LLM technologies offer unprecedented opportunities for enhancing accessibility for the blind and visually impaired, their widespread adoption is accompanied by significant technical limitations and complex ethical considerations that require careful attention.

10.5.1 Technical Limitations

Current AI systems, particularly those relying on computer vision, demonstrate high recognition accuracy rates (85-95%) for common objects and text in controlled environments. However, this performance often drops significantly (to 60-75%) in challenging real-world conditions characterized by poor lighting, complex scenes, or diverse object presentations. This performance gap underscores the critical need for more robust systems that can operate reliably across varied and unpredictable environments.[201]

Response time is another crucial factor impacting the utility of these devices. User studies indicate that feedback delays exceeding 1.5 seconds significantly diminish the usefulness of assistive technologies, particularly for real-time tasks like navigation or object detection. Achieving real-time performance for complex scene understanding remains a persistent challenge.[202] Furthermore, battery life continues to be a limiting factor for many wearable assistive devices, with most current solutions requiring recharging after only 3-5 hours of active use. This duration often falls short of covering a full day of activities, necessitating frequent recharging or carrying backup power.[203] Computational requirements also pose a challenge, as running large language models locally on portable devices often requires offloading intensive tasks to cloud services, which can introduce latency and dependency on internet connectivity.[204]

[201] Source: https://www.aimodels.fyi/papers/arxiv/ai-powered-assistive-technologies-visual-impairment

[202] Source: https://www.aimodels.fyi/papers/arxiv/ai-powered-assistive-technologies-visual-impairment

[203] Source: https://www.aimodels.fyi/papers/arxiv/ai-powered-assistive-technologies-visual-impairment

[204] Source: https://www.themoonlight.io/en/review/seesay-an-assistive-device-for-the-visually-impaired-using-retrieval-augmented-generation

10.5.2 Data Quality and Bias

A significant concern revolves around data quality and the inherent biases within AI models. NLP models, for instance, require vast amounts of high-quality data for effective training and improvement. However, collecting and annotating data specifically for accessibility purposes can be challenging, particularly for low-resource languages or highly specialized domains.[205] AI models can also be prone to bias and inaccuracies if their training data is not representative of diverse user groups or contains existing societal biases. This can result in suboptimal performance and a negative user experience, leading to what is termed "misfitting" in computer vision systems.[206]

The concept of "misfitting" highlights that AI technologies are predominantly built for sighted individuals using sighted data, leading to systems that may not adequately support the unique needs and lived experiences of blind users. This is particularly evident when AI Visual Assistance Technologies (AI VAT) fail to support complex document layouts, diverse languages, or cultural artifacts, causing an additional layer of misfitting for blind individuals who hold marginalized identities.[207] For example, GenAI tools have been observed to struggle with nuanced concepts about disability, sometimes producing stereotypical characterizations (e.g., describing blind people as 'courageous' or 'resilient') or even expressing pity (e.g., "I'm sorry, you're blind"), which can be frustrating for users.[208] Participants in studies hypothesize that biased datasets, often created by non-disabled people, are a key reason for such ableist and inappropriate GenAI responses.[209] Concerns also extend to biased portrayals of race and gender, such as misgendering or inaccuracies in low-resource languages due to underrepresentation in datasets.[210]

10.5.3 Accessibility of AI Interfaces

Even with powerful AI capabilities, the user interfaces of GenAI tools can present significant accessibility challenges for blind individuals. Users have reported that buttons

[205] Source: https://www.numberanalytics.com/blog/ultimate-guide-nlp-accessibility

[206] Source: https://www.numberanalytics.com/blog/ultimate-guide-nlp-accessibility; https://rahaf.info/data/ASSETS2024.pdf; https://www.researchgate.net/publication/385286169_Misfitting_With_AI_How_Blind_People_Verify_and_Contest_AI_Errors

[207] Source: https://rahaf.info/data/ASSETS2024.pdf; https://arxiv.org/html/2408.06546v1

[208] Source: https://maitraye.github.io/files/papers/BLV_GenAI_ASSETS24.pdf

[209] Source: https://maitraye.github.io/files/papers/BLV_GenAI_ASSETS24.pdf

[210] Source: https://maitraye.github.io/files/papers/BLV_GenAI_ASSETS24.pdf

for common actions like copying, regenerating, or downvoting responses in tools like ChatGPT are often unlabeled, forcing them to guess functions through trial and error. Furthermore, many GenAI interfaces, such as ChatGPT and Claude, lack appropriate heading labels, regions, or landmarks for screen reader users, making it difficult to quickly navigate conversations. Users often resort to ”brute force” methods, scrolling through entire conversations with arrow keys to find responses or type new prompts.[211]

Users of Copilot and Bard have expressed frustration with extraneous sample prompts and advertisements, which create ”a lot of clutter to sort through” before reaching the chat fields. Additionally, blind users often do not receive immediate notifications when the system finishes generating a response, requiring them to actively ”dig for it” by moving their screen reader focus. While some of these issues might affect sighted users, their impact is magnified for blind individuals using screen readers, which can significantly slow down the interaction and make the experience frustrating.[212]

10.5.4 Verification and Trust

A critical challenge for blind users of AI VAT is verifying the accuracy of AI-generated outputs, especially when the information is visual and cannot be independently confirmed. GenAI tools frequently provide fabricated, inaccurate, or inconsistent information, a phenomenon known as ”hallucinations.” For instance, Be My AI might misidentify a raincoat pattern, or ChatGPT might replace a user’s name with a fictitious one.[213] A significant issue is that GenAI tools often project ”confidence” in their inaccurate responses, particularly concerning visual information, which can be highly misleading for blind users who cannot visually verify the information.[214]

Blind participants attempt to identify inaccuracies by sensing if responses ”sounded really weird” or were ”very different” from their expectations. They resort to external verification methods, such as ”turning to Google” or consulting reliable websites. They also try to verify by repeating questions to the same tool or using multiple GenAI tools to check for consistent responses. ”Deductive reasoning” is employed by asking follow-up questions to judge accuracy or completeness. The decision to verify depends on the context of use (e.g., medical, financial, professional information requires high verification), the stakes involved (higher stakes necessitate more rigorous verification), the ease of verifiability (which is harder for blind users without sighted help), and the believability of the information. The richness and detail of GenAI responses, while

[211] Source: https://maitraye.github.io/files/papers/BLV_GenAI_ASSETS24.pdf
[212] Source: https://maitraye.github.io/files/papers/BLV_GenAI_ASSETS24.pdf
[213] Source: https://maitraye.github.io/files/papers/BLV_GenAI_ASSETS24.pdf
[214] Source: https://maitraye.github.io/files/papers/BLV_GenAI_ASSETS24.pdf

beneficial for access, can be a "double-edged sword," as they also increase the likelihood of trusting inaccurate information.[215]

10.5.5 Privacy and Data Security

Concerns regarding privacy are substantial, with 78% of users expressing worries about continuous recording in public spaces and the security of their personal data.[216] Users have limited understanding of how GenAI tools store and use their information, leading to apprehension about privacy, especially given the ability to retrieve previous chat history.[217] The proliferation of misinformation, disinformation, deep fake videos, and voice cloning scams facilitated by GenAI also raises concerns among users, who exercise caution before using GenAI responses in publicly shared content to avoid "creating more fake news".[218]

10.5.6 Ethical Imperatives

Ensuring that AI systems are accessible to everyone, regardless of their abilities, is not merely a moral obligation but also a legal requirement in many jurisdictions, such as the European Union's Accessibility Act and the United States' Americans with Disabilities Act (ADA).[219] The moral argument for accessible AI is rooted in the principles of equality and non-discrimination, asserting that people with disabilities should have equal access to the benefits and opportunities provided by AI technologies.[220] Inaccessible AI systems can exacerbate existing inequalities by excluding individuals with disabilities from fully participating in society.[221]

Key practices for ensuring accessibility in AI development include integrating accessibility considerations early in the development process, conducting accessibility audits, incorporating accessibility features into design and testing phases, and ensuring compatibility with assistive technologies like screen readers.[222] Engaging with users with

215 Source: `https://maitraye.github.io/files/papers/BLV_GenAI_ASSETS24.pdf`
216 Source: `https://www.aimodels.fyi/papers/arxiv/ai-powered-assistive-technologies-visual-impairment`
217 Source: `https://maitraye.github.io/files/papers/BLV_GenAI_ASSETS24.pdf`
218 Source: `https://maitraye.github.io/files/papers/BLV_GenAI_ASSETS24.pdf`
219 Source: `https://www.numberanalytics.com/blog/ethics-ai-accessibility-matters`
220 Source: `https://www.numberanalytics.com/blog/ethics-ai-accessibility-matters`
221 Source: `https://www.numberanalytics.com/blog/ethics-ai-accessibility-matters`
222 Source: `https://www.numberanalytics.com/blog/ultimate-guide-nlp-accessibility`; `https://www.microsoft.com/en-us/research/publication/ai-and-accessibility-a-discussion-of-ethical-considerations/`; `https://www.numberanalytics.com/blog/ethics-ai-accessibility-matters`

disabilities throughout the development process is crucial for creating truly accessible AI. This involves conducting user research to understand diverse needs, involving users in usability testing, and collaborating with disability organizations to gain insights and feedback.[223] Continuous improvement is also vital, requiring regular updates to AI systems for compatibility with the latest assistive technologies, monitoring user feedback for emerging issues, and continuously evaluating and improving the accessibility of AI algorithms and models.[224] The development of AI must be guided by the principles of inclusivity and respect for human rights.[225]

10.6 The Imperative of Locally Hosted LLMs for Privacy and Accessibility

While cloud-based Large Language Models (LLMs) offer convenience and scalability, their reliance on external servers introduces significant privacy and accessibility challenges. For a truly inclusive and secure AI ecosystem, the availability and adoption of locally hosted LLMs through services and frameworks like 'llamafile', 'llama.cpp', and 'Ollama' become paramount.

10.6.1 Privacy Considerations

A primary concern with cloud-based LLMs is data privacy. When users interact with these models, their inputs, queries, and often the generated outputs are transmitted to and processed by third-party servers. This raises questions about:

- *Data Security and Confidentiality:* Sensitive personal information, medical data, financial details, or proprietary business information processed by cloud LLMs could be at risk of breaches or unauthorized access by the service provider or other malicious actors. For individuals with disabilities, this can include highly personal information related to their health or assistance needs, making privacy even more critical [226].

[223] Source: https://www.microsoft.com/en-us/research/publication/ai-and-accessibility-a-discussion-of-ethical-considerations/; https://www.numberanalytics.com/blog/ethics-ai-accessibility-matters

[224] Source: https://www.numberanalytics.com/blog/ethics-ai-accessibility-matters

[225] Source: https://www.numberanalytics.com/blog/ethics-ai-accessibility-matters

[226] DataNorth AI. (2025, May 15). *Local LLM: Privacy, Security, and Control*. Retrieved from https://datanorth.ai/blog/local-llms-privacy-security-and-control; IGNESA. (2025, June 8). *The Truth About Local LLMs: When You Actually Need Them*. Retrieved from https://ignesa.com/insights/the-truth-about-local-llms-when-you-actually-need-them/

- *Data Retention and Usage Policies:* Users often have limited control over how their data is stored, used, and potentially utilized for model training by cloud providers [227]. This lack of transparency can be a major deterrent for privacy-conscious individuals and organizations.
- *Regulatory Compliance:* Industries such as healthcare (e.g., HIPAA) and finance have stringent data privacy regulations. Locally hosted LLMs enable organizations to maintain data sovereignty and comply with these laws by ensuring data remains within their controlled environment [228].

Locally hosted LLMs, by processing all data on the user's device or private network, eliminate these concerns. The data never leaves the user's control, offering complete confidentiality and peace of mind [229]. This is particularly beneficial for accessibility applications where highly personal information might be involved, such as individualized communication aids or specialized educational tools.

10.6.2 Accessibility Benefits Beyond Privacy

Beyond privacy, locally hosted LLMs offer several accessibility advantages:

- *Offline Functionality:* Many individuals, particularly those in remote areas or with unreliable internet access, may struggle to use cloud-based AI. Locally hosted models operate entirely offline, ensuring continuous access to AI capabilities regardless of connectivity [230]. This is vital for critical accessibility tools that cannot afford internet dependency.
- *Reduced Latency and Improved Responsiveness:* Communication with cloud servers introduces latency, which can be disruptive for real-time accessibility applications like live captioning, assistive communication, or interactive learning

[227] UpGuard. (2025, June 26). *Analyzing llama.cpp Servers for Prompt Leaks*. Retrieved from https://www.upguard.com/blog/llama-cpp-prompt-leak

[228] God of Prompt. (2025, June 25). *Local LLM Setup for Privacy-Conscious Businesses*. Retrieved from https://www.godofprompt.ai/blog/local-llm-setup-for-privacy-conscious-businesses

[229] DataNorth AI. (2025, May 15). *Local LLM: Privacy, Security, and Control*. Retrieved from https://datanorth.ai/blog/local-llms-privacy-security-and-control; Foojay. (2025, May 6). *Local AI with Spring: Building Privacy-First Agents Using Ollama*. Retrieved from https://foojay.io/today/local-ai-with-spring-building-privacy-first-agents-using-ollama/

[230] God of Prompt. (2025, June 25). *Local LLM Setup for Privacy-Conscious Businesses*. Retrieved from https://www.godofprompt.ai/blog/local-llm-setup-for-privacy-conscious-businesses; Intrada Technologies. (2025, March 28). *Cloud vs. Local LLMs: Which AI Powerhouse is Right for You?*. Retrieved from https://www.intradatech.com/hosting-and-cloud/tech-talk/cloud-vs-local-ll-ms-which-ai-powerhouse-is-right-for-you

tools. Local LLMs offer significantly faster response times, providing a smoother and more efficient user experience [231].

- *Cost-Effectiveness (Long-Term):* While initial setup costs for local hardware might be present, for frequent and high-volume usage, locally hosted LLMs can be more cost-effective in the long run by eliminating recurring subscription fees and data transfer costs associated with cloud services [232]. This can make powerful AI tools more accessible to individuals and smaller organizations with limited budgets.
- *Customization and Fine-Tuning:* Locally hosted models offer greater control over customization and fine-tuning. Users and developers can adapt the models to specific needs, accents, communication styles, or domain-specific knowledge without reliance on third-party policies or services [233]. This is crucial for creating highly personalized and effective accessibility solutions.
- *Empowerment and Digital Sovereignty:* Running LLMs locally empowers users by giving them full control over their AI tools. This fosters digital sovereignty, allowing individuals to utilize advanced technology without ceding control of their data or relying on external entities [234].

10.6.3 Enabling Technologies: 'llamafile', 'llama.cpp', and 'Ollama'

The growing ecosystem of tools facilitating local LLM deployment is critical for advancing AI accessibility:

- *'llama.cpp':* This project, developed by Georgi Gerganov, is a foundational library that enables efficient inference of LLMs on consumer hardware, even CPUs, through

[231] God of Prompt. (2025, June 25). *Local LLM Setup for Privacy-Conscious Businesses*. Retrieved from `https://www.godofprompt.ai/blog/local-llm-setup-for-privacy-conscious-businesses`; sideEffekt. (2024, July 20). *Benefits of Local Large Language Models*. Retrieved from `https://sideeffekt.com/2024/07/20/benefits-of-local-large-language-models/`

[232] God of Prompt. (2025, June 25). *Local LLM Setup for Privacy-Conscious Businesses*. Retrieved from `https://www.godofprompt.ai/blog/local-llm-setup-for-privacy-conscious-businesses`; DataCamp. (2023, May 23). *The Pros and Cons of Using LLMs in the Cloud Versus Running LLMs Locally*. Retrieved from `https://www.datacamp.com/blog/the-pros-and-cons-of-using-llm-in-the-cloud-versus-running-llm-locally`

[233] Intrada Technologies. (2025, March 28). *Cloud vs. Local LLMs: Which AI Powerhouse is Right for You?*. Retrieved from `https://www.intradatech.com/hosting-and-cloud/tech-talk/cloud-vs-local-ll-ms-which-ai-powerhouse-is-right-for-you`

[234] Chatterjee, A. (2025, May 27). *The future of AI should be private, try Open WebUI and Ollama*. HEY World. Retrieved from `https://world.hey.com/akashc/the-future-of-ai-should-be-private-try-open-webui-and-ollama-a6e829f8`

techniques like quantization [235]. Its efficiency makes powerful LLMs accessible on a wider range of devices.

- *'llamafile':* Built upon 'llama.cpp' and Cosmopolitan Libc, 'llamafile' simplifies LLM distribution and execution by packaging a complete LLM into a single, portable executable file [236]. This "single-file executable" approach dramatically lowers the barrier to entry for running LLMs locally, requiring no complex installations or dependencies, and works across multiple operating systems. This significantly enhances accessibility for users who may lack technical expertise or robust computing environments [237].
- *'Ollama':* 'Ollama' provides a user-friendly platform for downloading, running, and managing a variety of open-source LLMs locally [238]. It simplifies the process of setting up a local LLM server and interacting with models, further democratizing access to powerful AI capabilities for a broad audience. While 'Ollama' enhances ease of use, it's important for users to be aware of security best practices, as some configurations could expose data if not properly managed [239].

By promoting and supporting these and similar locally-focused technologies, we can ensure that the benefits of advanced AI are accessible to everyone, fostering innovation and independence without compromising privacy or reliance on external infrastructure.

10.6.4 Other Promising Ecosystems and Considerations for Local LLMs

Beyond 'llama.cpp' and 'Ollama', several other projects and frameworks are contributing to the local LLM ecosystem, some with explicit or implicit benefits for accessibility,

[235] Codecademy. (n.d.). *How to Use llama.cpp to Run LLaMA Models Locally*. Retrieved from `https://www.codecademy.com/article/llama-cpp`; KDnuggets. (2025, June 24). *Building AI Agents with llama.cpp*. Retrieved from `https://www.kdnuggets.com/building-ai-agent-with-llama-cpp`

[236] Analytics Vidhya. (2024, January 24). *Using Llamafiles to Simplify LLM Execution*. Retrieved from `https://www.analyticsvidhya.com/blog/2024/01/using-llamafiles-to-simplify-llm-execution/`; Mozilla-Ocho. (n.d.). *llamafile: Distribute and run LLMs with a single file.* GitHub. Retrieved from `https://github.com/Mozilla-Ocho/llamafile`

[237] BytePlus. (n.d.). *Llamafile: Bringing LLMs to the People, and to Your Own Computer*. Retrieved from `https://www.byteplus.com/en/topic/464464`

[238] DEV Community. (2025, January 29). *Unlocking AI's Potential: Ollama's Local Revolution in AI Development*. Retrieved from `https://dev.to/sina14/unlocking-ais-potential-ollamas-local-revolution-in-ai-development-1945`; Foojay. (2025, May 6). *Local AI with Spring: Building Privacy-First Agents Using Ollama*. Retrieved from `https://foojay.io/today/local-ai-with-spring-building-privacy-first-agents-using-ollama/`

[239] Ridge Security. (2025, March 20). *Securing Your AI: Critical Vulnerabilities Found in Popular Ollama Framework*. Retrieved from `https://ridgesecurity.ai/blog/securing-your-ai-critical-vulnerabilities-found-in-popular-ollama-framework/`

especially when integrated into user-facing applications.

User-Friendly Frontends and Desktop Applications

For screen reader users, the graphical user interface (GUI) or command-line interface (CLI) of the *application* interacting with the local LLM is paramount. Some notable efforts in this space include:

- *LM Studio:* This provides a desktop application with a graphical user interface for discovering, downloading, and running various LLMs locally (often leveraging ‘llama.cpp‘ under the hood) [240]. Its user-friendly interface could potentially be more accessible than command-line tools for some users, depending on the implementation of its UI elements for screen readers.
- *Jan:* Positioned as an open-source, lightweight alternative offering both frontend and backend features for running local LLMs, Jan aims for a clean and elegant UI [241]. Its focus on user experience suggests a higher likelihood of screen reader compatibility compared to raw command-line tools.
- *GPT4All:* This is an ”all-in-one” application that mirrors a ChatGPT-like interface and is designed for quickly running local LLMs for common tasks [242]. Its end-user focus can mean more attention is paid to the overall usability, including potential screen reader support.
- *Oobabooga Text Generation Web UI:* This is a highly popular and feature-rich web-based interface for running and interacting with local language models, supporting many backend loaders including ‘llama.cpp‘ [243]. As a web UI, its accessibility largely depends on adherence to web accessibility standards (WCAG), which is a key consideration for screen reader users.

---

[240] GetStream.io. (n.d.). *The 6 Best LLM Tools To Run Models Locally*. Retrieved from https://getstream.io/blog/best-local-llm-tools/

[241] Lam, V. (2024, March 12). *50+ Open-Source Options for Running LLMs Locally*. The Deep Hub. Retrieved from https://medium.com/thedeephub/50-open-source-options-for-running-llms-locally-db1ec6f5a54f

[242] Lam, V. (2024, March 12). *50+ Open-Source Options for Running LLMs Locally*. The Deep Hub. Retrieved from https://medium.com/thedeephub/50-open-source-options-for-running-llms-locally-db1ec6f5a54f

[243] Lam, V. (2024, March 12). *50+ Open-Source Options for Running LLMs Locally*. The Deep Hub. Retrieved from https://medium.com/thedeephub/50-open-source-options-for-running-llms-locally-db1ec6f5a54f

Frameworks for Building LLM Applications

While not direct LLM inference engines themselves, these frameworks are crucial for building accessible applications that *leverage* local LLMs:

- LangChain and LlamaIndex: These are popular open-source frameworks designed to streamline the development of applications powered by LLMs. They simplify building workflows that combine LLMs with external data sources (like Retrieval Augmented Generation, RAG), APIs, or computational logic [244]. The accessibility of applications built with these frameworks will depend on the developers' implementation choices for the user interface, but their existence makes it easier to create sophisticated, locally-powered AI tools.
- Hugging Face Transformers: This is a widely used library offering a comprehensive collection of pre-trained models and tools for various NLP tasks, including inference. While often associated with cloud services, it can also be used for local inference and is a cornerstone for many open-source LLM projects [245]. Its robustness and community support can indirectly aid in the development of accessible applications.

Specialized Accessibility-Focused LLM Applications/Research

It's also important to acknowledge emerging research and specific projects that directly address accessibility challenges using LLMs, which may or may not heavily rely on a single backend like 'llama.cpp' or 'Ollama':

- MATE (LLM-Powered Multi-Agent Translation Environment for Accessibility Applications): This is a multi-agent system designed for modality adaptation tasks, such as converting images to audio descriptions for visually impaired users [246]. While a research project, it highlights the potential for localized LLMs to directly provide accessibility solutions through various modality conversions, which would inherently need to be screen reader compatible in their output.
- DexAssist: A voice-enabled dual-LLM framework designed for accessible web navigation, aiming to assist individuals with fine motor impairments [247]. Such

[244] Zilliz blog. (2025, January 2). *10 Open-Source LLM Frameworks Developers Can't Ignore in 2025*. Retrieved from `https://zilliz.com/blog/10-open-source-llm-frameworks-developers-cannot-ignore-in-2025`

[245] BytePlus. (n.d.). *Best Alternatives for llama.cpp*. Retrieved from `https://www.byteplus.com/en/topic/497811`

[246] arxiv.org. (2025, June 24). *MATE: LLM-Powered Multi-Agent Translation Environment for Accessibility Applications*. Retrieved from `https://arxiv.org/html/2506.19502v1`

[247] arXiv. (2024, November 5). *DexAssist: A Voice-Enabled Dual-LLM Framework for Accessible Web Navigation*. Retrieved from `https://arxiv.org/html/2411.12214v1`

systems demonstrate the direct application of LLMs (potentially local) to improve digital accessibility, where screen reader compatibility would be a core requirement for user interaction and feedback.

When discussing screen reader accessibility for local LLM ecosystems, it's crucial to emphasize that the underlying inference engine (like 'llama.cpp') often doesn't have a direct user interface to interact with. Instead, the accessibility largely depends on the *applications* built on top of these engines. Therefore, promoting frameworks and tools that prioritize user-friendly GUIs and adherence to accessibility standards (like WCAG for web UIs) is key for ensuring these powerful local AI capabilities are truly accessible to all, including screen reader users.

10.6.5 Affordability and Equitable Access

The cost of advanced AI assistive systems remains a significant barrier for many potential users. High-end systems are often priced between $2,000 and $5,000, creating substantial accessibility barriers for those who could benefit most from these technologies.[248] Ensuring affordability and equitable access is crucial for widespread adoption and to prevent exacerbating existing inequalities.

10.7 Conclusion

The recent emergence of AI and LLM-based technologies marks a pivotal moment in enhancing accessibility for blind and visually impaired individuals. These advancements are profoundly transforming daily living, educational pursuits, professional productivity, and recreational activities, fostering unprecedented levels of independence and participation.

In daily living and mobility, AI-powered tools have evolved from basic object identification to comprehensive environmental understanding, providing contextual comprehension and predictive guidance. Devices like SeeSay, NOA, Envision Glasses, and NaviLens offer real-time scene descriptions, intelligent navigation, and seamless information access, significantly improving safety and autonomy in navigating complex environments. The ability of conversational AI to bridge digital and physical information gaps further empowers individuals to interact with their surroundings and manage everyday tasks with greater ease.

[248] Source: `https://www.aimodels.fyi/papers/arxiv/ai-powered-assistive-technologies-visual-impairment`

Within educational and professional settings, AI and LLMs are democratizing access to information and fostering personalized learning experiences. Tools like NotebookLM, Be My AI, and Access AI convert traditional learning materials into accessible formats and provide individualized tutoring, allowing students to engage with complex concepts and develop skills without judgment. In the workplace, AI-powered digital assistants such as Copilot, Microsoft Teams, and Read AI Meeting notes are augmenting productivity, automating tasks, and facilitating inclusive communication, enabling visually impaired professionals to participate fully and independently in the modern workforce. The application of NLP to analyze accessibility feedback represents a crucial closed-loop system for continuous improvement, ensuring that future AI solutions are human-centered and responsive to user needs.

In the realm of recreation and leisure, AI is opening new avenues for engagement. Accessible gaming frameworks like GamerAstra are translating visual game experiences into rich auditory narratives, while AI tools are democratizing creative arts and music production, allowing blind individuals to generate visual art from text or compose music through voice commands. In sports, technologies like Touch2See are providing immersive real-time experiences through haptic feedback and audio descriptions, fostering greater participation and enjoyment.

Despite these transformative advancements, significant challenges persist. Technical limitations related to accuracy in complex environments, latency, and battery life require ongoing research and development. Ethical considerations surrounding data quality, algorithmic bias, and the ”misfitting” of AI systems designed primarily for sighted users are paramount. These issues can lead to inaccuracies, ableist content, and a diminished user experience. Furthermore, the accessibility of AI interfaces themselves often falls short, with unlabeled elements and poor navigation hindering usability for screen reader users. Concerns about privacy, data security, and the high cost of advanced systems also present considerable barriers to equitable access.

Addressing these challenges necessitates a commitment to human-centered design, active engagement with the visually impaired community throughout the development lifecycle, and continuous iteration based on user feedback. Prioritizing accessibility is not merely a technical or legal requirement but a fundamental ethical imperative to ensure that AI's transformative potential is realized inclusively for everyone. The continued evolution of AI and LLM technologies holds immense promise for creating a more accessible, equitable, and empowering world for blind and visually impaired students and adults, enabling them to succeed comprehensively in all facets of life.

Chapter 11

Comprehensive Analysis of Accessible Music Braille Transcription Solutions

11.1 abstract

The landscape of music braille transcription is characterized by a dynamic interplay of technological advancements and a profound commitment to accessibility. This report provides a thorough examination of open-source, GitHub-hosted, and commercial software solutions designed to convert standard sheet music into music braille code. The analysis spans the entire transcription pipeline, from initial input methods to the generation of various braille formats, with a particular emphasis on tools that prioritize accessibility and screen reader compatibility for visually impaired users.

A significant observation within this domain is the existence of two primary approaches to music braille production. One method involves automated translation from print or digital notation, such as MusicXML, which offers considerable efficiency for large-scale transcription tasks. The other approach centers on direct, braille-centric input and editing, a method often favored for producing high-quality, nuanced scores tailored specifically for tactile readability. The presence of both methodologies underscores a maturing field that addresses diverse user workflows and preferences, recognizing that a simple one-to-one translation from print notation may not always yield the most effective braille output.

Central to the interoperability of this ecosystem is MusicXML, which functions as a critical, widely adopted standard. Its pervasive use by mainstream music notation

software establishes it as the de facto bridge for accessibility, facilitating seamless data exchange across a diverse array of transcription tools.[1] Without MusicXML, the integration between various notation programs and braille transcription software would be severely hampered, leading to fragmented and less efficient solutions for accessible music.

Furthermore, a substantial portion of the innovation and enhancement in accessible music braille tools, particularly within the open-source sector, is propelled by community contributions and non-profit initiatives. This collaborative spirit, extending beyond commercial interests, is evident in projects that welcome external contributions and in the concerted efforts of organizations like the DAISY Consortium to develop and standardize accessible music formats.[2] This demonstrates that a passionate community and dedicated non-profit sector are indispensable for advancing accessibility in this specialized yet vital area, frequently addressing needs that commercial ventures might not prioritize.

11.2 Understanding Music Braille: Fundamentals and Unique Considerations

11.2.1 Introduction to Braille Music Notation

Braille music notation is a specialized tactile system that enables visually impaired individuals to read and comprehend musical scores. It employs combinations of the standard six-dot braille cell to represent both the pitch and rhythm of each note. Typically, the top two rows of the braille cell convey pitch information, while the bottom row is dedicated to rhythmic values.[3]

A fundamental distinction between braille music and conventional stave notation lies in its linearity. Unlike stave notation, where notes in chords are often displayed vertically and various musical signs can appear above or below, braille music signs must be presented strictly from left to right, one at a time.[4] This sequential arrangement dictates the order of musical elements: dynamic markings, accents, staccato signs, accidentals, and octave indications precede the note, while signs for added duration, harmonic

---

[1] `https://digitalstrategy.unt.edu/clear/teaching-resources/accessibility/music-accessibility/braille-music-resources.html`

[2] `https://daisy.org/activities/projects/music-braille/latest-developments/`

[3] `https://www.rnib.org.uk/living-with-sight-loss/education-and-learning/braille-tactile-codes/braille-music/`

[4] `https://www.rnib.org.uk/living-with-sight-loss/education-and-learning/braille-tactile-codes/braille-music/`

indications, fingering numbers, and slur signs follow it.[5]

Chords in braille music are represented uniquely to accommodate the linear format. Instead of displaying all notes of a chord simultaneously, only one note is explicitly written, with the remaining notes indicated by special interval signs that immediately follow the primary note.[6] For example, a C major chord played by the right hand on a piano might begin with an eighth note G, followed by an interval of a third to denote E, and then an interval of a fifth to denote C. A crucial rule is that all notes within a braille chord must share the same rhythmic value.[7] There are seven distinct interval signs in braille music, each corresponding to a specific dot pattern for seconds, thirds, fourths, fifths, sixths, sevenths, and octaves.[8] Octave signs are also essential for precise pitch indication, with specific braille marks representing each of the seven complete octaves on an 88-key piano.[9]

11.2.2 Comparison with Standard Print Notation

The core difference between braille music and standard print notation is their spatial organization. Print music allows for a vertical and layered display of information, enabling simultaneous comprehension of chords, dynamics, and articulations. Braille music, by contrast, is inherently linear and tactile.[10] This linearity significantly impacts how music is perceived and processed by the musician.

Space is another critical factor. A single bar of braille music can consume considerably more physical space than its print counterpart, often resulting in only one bar per page.[11] To conserve space and improve readability, braille music frequently incorporates repeat signs for beats, part-bars, or whole bars.[12]

The tactile nature of braille music also imposes a unique cognitive demand. Reading

5 https://www.rnib.org.uk/living-with-sight-loss/education-and-learning/braille-tactile-codes/braille-music/
6 https://blogs.loc.gov/nls-music-notes/2023/11/braille-music-basics-intervals/
7 https://blogs.loc.gov/nls-music-notes/2023/11/braille-music-basics-intervals/
8 https://blogs.loc.gov/nls-music-notes/2023/11/braille-music-basics-intervals/
9 https://musescore.org/en/handbook/4/braille
10 https://www.rnib.org.uk/living-with-sight-loss/education-and-learning/braille-tactile-codes/braille-music/
11 https://www.rnib.org.uk/living-with-sight-loss/education-and-learning/braille-tactile-codes/braille-music/
12 https://www.rnib.org.uk/living-with-sight-loss/education-and-learning/braille-tactile-codes/braille-music/

braille with the hands typically makes it impossible to simultaneously read and play an instrument, with pianists being a notable exception. Singers, while capable of sight-reading with practice, often find it necessary to memorize either the lyrics or the music due to the difficulty of reading both concurrently.[13] Consequently, a musician reading braille may require significantly more time to learn a score compared to a print reader.[14]

11.2.3 The Imperative for Accessible Music Notation

Braille sheet music serves as an indispensable tool for fostering inclusivity and independence among musicians with visual impairments.[15] It grants them the ability to deeply engage with musical compositions, participate in ensembles, and pursue their musical aspirations on an equal footing with their sighted peers.[16] The advent of digital technology has profoundly enhanced this inclusivity, enabling visually impaired musicians to efficiently access and navigate extensive libraries of braille music.[17]

The inherent differences between print and braille music notation, particularly the linear reading structure, space constraints, and the necessity of memorization, mean that effective braille music transcription is not merely a direct translation. Instead, it requires a thoughtful re-composition specifically for tactile readability. Tools that prioritize a "braille-first" design or facilitate direct braille input are therefore crucial for generating high-quality, legible scores that genuinely serve the needs of the blind musician.[18] This approach recognizes that automatic translation engines, while convenient, often produce unpolished, inefficient, or even inaccurate results because they do not fully account for the unique tactile and cognitive demands of braille music.[19]

The linear nature and substantial space requirements of braille music, combined with the physical act of reading with hands, impose a considerable cognitive load. This often necessitates memorization for performance, as simultaneous reading and playing is generally not feasible.[20] This implies that transcription tools must not only be accurate in their conversion but also optimize formatting for ease of memorization and navigation.

[13] https://www.rnib.org.uk/living-with-sight-loss/education-and-learning/braille-tactile-codes/braille-music/
[14] https://www.rnib.org.uk/living-with-sight-loss/education-and-learning/braille-tactile-codes/braille-music/
[15] https://braillemusicandmore.com/braille-sheet-music-guide/
[16] https://braillemusicandmore.com/braille-sheet-music-guide/
[17] https://braillemusicandmore.com/braille-sheet-music-guide/
[18] https://www.pathstoliteracy.org/resource/braille-music-notator/
[19] https://www.pathstoliteracy.org/resource/braille-music-notator/
[20] https://www.rnib.org.uk/living-with-sight-loss/education-and-learning/braille-tactile-codes/braille-music/

Features such as synchronized playback with audio cues become critical compensatory mechanisms, and the choice of braille music format (e.g., bar-over-bar, line-by-line, or paragraph formats) directly influences the practicality of using the braille score during performance.[21] This highlights a deeper requirement for tools to support the learning and memorization process, extending beyond mere translation, to truly empower visually impaired musicians.

11.3 The Music Braille Generation Pipeline: Stages and Technologies

The process of converting standard sheet music into accessible music braille involves several distinct stages, each supported by specialized technologies and software.

11.3.1 Input Stage

The initial phase of the pipeline focuses on getting the musical data into a digital format suitable for transcription.

Optical Music Recognition (OMR) for Print Scores

Optical Music Recognition (OMR) systems aim to transform scanned print music scores into structured digital formats, most commonly MusicXML.[22] This technology holds significant promise for automating the input of existing print scores. While deep learning has led to considerable advancements in OMR for printed scores, the recognition of handwritten music remains a less developed area of research.[23]

Some music notation software, such as MuseScore, is developing OMR capabilities. Its current framework can recognize staves and barlines, with future potential for full note entry.[24] However, the accuracy and speed of OMR, particularly for small symbols like note heads, still present challenges, and comprehensive training data from diverse fonts is needed for further improvement.[25] While traditional OMR pipelines involve multiple

21 `https://www.dancingdots.com/main/goodfeel.htm`
22 `https://www.researchgate.net/figure/The-classes-of-symbols-from-MuseScore-used-in-our-work-These-symbols-are-depicted_fig2_334137649`
23 `https://www.researchgate.net/figure/The-classes-of-symbols-from-MuseScore-used-in-our-work-These-symbols-are-depicted_fig2_334137649`
24 `https://musescore.org/en/node/110306`
25 `https://musescore.org/en/node/110306`

stages, modern deep learning approaches like YOLO are streamlining this process into single-stage detection.[26]

Despite these advancements, OMR for music notation is not yet a seamless, highly accurate solution for complex music braille. Tools like GOODFEEL, which allow scanning print scores as an optional input, explicitly state that a sighted musician must correct any errors introduced during the scanning process.[27] This indicates that for generating high-quality braille music, MusicXML import and manual braille-centric input remain more reliable and accessible pathways. OMR is more of a future potential than a current robust solution for complex music braille. SharpEye Music Reader, bundled with Lime Aloud, also offers music OCR capabilities.[28]

11.4 Optical Music Recognition: SharpEye and Commercial Scanning Solutions

Optical Music Recognition (OMR) or music scanning software represents a crucial bridge between printed musical scores and digital accessibility. These commercial solutions enable the conversion of printed sheet music into digital formats that can subsequently be processed by braille music translation software, making printed music accessible to blind and visually impaired musicians.

11.4.1 SharpEye Music Scanning Software

SharpEye, developed by Visiv Ltd., is a well-established optical music recognition program that has been integrated into various music accessibility workflows, particularly in conjunction with GOODFEEL and other braille music translation systems.

Technical Capabilities

SharpEye converts printed sheet music into digital music notation files through optical character recognition specifically designed for musical symbols. The software outputs multiple formats including MIDI, NIFF, and MusicXML, making it compatible with a wide range of music notation software and braille translation systems.

26 `https://www.researchgate.net/figure/The-classes-of-symbols-from-MuseScore-used-in-our-work-These-symbols-are-depicted_fig2_334137649`
27 `https://www.dancingdots.com/main/goodfeel.htm`
28 `https://canasstech.com/products/lime-aloud`

Integration with Braille Music Workflow

SharpEye plays a crucial role in the GOODFEEL ecosystem, where it serves as the primary method for digitizing printed music scores. The typical workflow involves scanning printed music with SharpEye, which then exports the recognized music to MusicXML or NIFF format for import into Lime (GOODFEEL's notation editor). This integration enables blind musicians to access printed music that would otherwise require manual transcription by sighted musicians.

Accuracy and Limitations

Like all optical music recognition software, SharpEye requires clean, well-printed musical scores for optimal results. While the software can achieve high accuracy with professionally engraved music, handwritten scores and poor-quality prints may require significant manual correction. The software includes an interactive editing environment that allows users to correct recognition errors before exporting to other applications.

Accessibility Features

SharpEye includes several features that enhance accessibility for users with visual impairments:

- Screen reader compatibility for navigation through the recognition interface
- Keyboard shortcuts for common editing operations
- Integration with TWAIN-compatible scanners for direct image acquisition
- Support for batch processing of multiple pages

11.4.2 Commercial Alternatives to SharpEye

The market for optical music recognition software includes several other commercial solutions, each with distinct strengths and target audiences.

PhotoScore Ultimate

Developed by Neuratron, PhotoScore Ultimate represents one of the most sophisticated commercial OMR solutions available. PhotoScore is integrated into Sibelius as its primary scanning engine and is also available as a standalone application.

Key Features:

- Advanced recognition accuracy with professionally printed music
- Support for complex musical elements including chord symbols, guitar tablature, and percussion notation
- Integration with NotateMe for handwritten music recognition
- Direct export to MusicXML and various proprietary formats
- Pricing ranges from approximately $70 for mobile versions to $250 for desktop applications

SmartScore Professional

Developed by Musitek, SmartScore represents a comprehensive solution for music scanning and editing. The software has evolved through multiple versions, with SmartScore 64 Pro being the current flagship product.

Capabilities:

- Comprehensive music recognition including complex orchestral scores
- Built-in music notation editor for post-scan corrections
- Multiple output formats including MusicXML, MIDI, and proprietary formats
- Transposition and arrangement capabilities
- Professional-grade accuracy with clearly printed music
- Pricing approximately $199 for the professional version

Historical Context: Reviews of SmartScore have consistently praised its accuracy with professionally engraved music while noting challenges with handwritten scores and user interface complexity. The software has been described as having ”no more effective” solution for clearly printed sheet music, though requiring significant learning investment.

ScanScore

ScanScore represents a newer entrant in the OMR market, offering tiered pricing and modern user interface design.

Product Range:

- Multiple versions available from $39 to $179 (€29 to €149)
- Cloud-based processing options for improved recognition accuracy
- Integration with popular notation software through MusicXML export
- Mobile app versions for tablet-based scanning

PDFtoMusic Pro

PDFtoMusic Pro occupies a specialized niche in the OMR market by focusing specifically on PDF files created by music notation software rather than scanned images.

Specialized Functionality:

- Optimized for PDF files generated by notation software (Finale, Sibelius, MuseScore)
- Higher accuracy rates when working with vector-based musical graphics
- Limited effectiveness with scanned or image-based PDFs
- Pricing approximately $199

11.4.3 Integration Challenges and Workflow Considerations

The integration of OMR software into braille music production workflows presents several technical and practical challenges that affect the overall accessibility of printed music.

Recognition Accuracy

All commercial OMR solutions require manual correction of recognition errors, with accuracy rates varying significantly based on:

- Quality of the original printed score
- Complexity of the musical notation
- Presence of annotations, fingerings, or other markings
- Font styles and engraving quality

Post-Processing Requirements

The output from OMR software typically requires significant editing before it can be effectively used for braille translation. This post-processing includes:

- Correction of note recognition errors
- Adjustment of rhythmic groupings and beaming
- Verification of key signatures and time signatures
- Addition of missing articulations and dynamics

Accessibility Barriers

The reliance on visual interfaces in most OMR software creates accessibility barriers for blind users:

- Recognition correction requires visual verification of musical symbols
- Most OMR software interfaces are not optimized for screen reader use
- The correction process often requires sighted assistance

11.4.4 Economic and Licensing Considerations

Commercial OMR software represents a significant investment for individuals and institutions working with music accessibility:

Cost Analysis

- Entry-level solutions: $39-$70 (basic scanning functionality)
- Professional solutions: $199-$250 (comprehensive features)
- Mobile solutions: $70-$100 (tablet-based scanning)

Licensing Models

Most commercial OMR software follows traditional perpetual licensing models, though some newer solutions offer subscription-based pricing. The investment in OMR software must be considered alongside the cost of braille translation software and associated hardware (scanners, braille displays, embossers).

11.4.5 Future Developments

The field of optical music recognition continues to evolve, with several trends impacting accessibility:

Machine Learning Integration

Modern OMR solutions increasingly incorporate machine learning algorithms to improve recognition accuracy and reduce manual correction requirements. These advances particularly benefit the accessibility workflow by reducing the need for sighted assistance in the correction process.

Cloud-Based Processing

Cloud-based OMR services offer improved recognition accuracy through access to more powerful processing resources and continuously updated recognition algorithms. This approach also enables better integration with web-based accessibility tools and services.

Mobile Integration

The development of mobile OMR applications enables more immediate access to printed music, allowing users to scan and process music scores using smartphones and tablets. This mobility is particularly valuable for blind musicians who may encounter printed music in various settings.

The commercial OMR market represents a critical component of the music accessibility ecosystem, providing the technological bridge between printed musical scores and digital accessibility tools. While these solutions require significant investment and typically involve manual correction processes, they enable access to the vast corpus of printed music that would otherwise remain inaccessible to blind and visually impaired musicians.

Audiveris

Audiveris is an open-source Optical Music Recognition (OMR) software developed in Java, available for Windows, macOS, and Linux.[29,30] Its primary function is to recognize printed music notation from scanned images or photos and convert it into a digital format, specifically MusicXML.[31] It can also recognize text within scores using Tesseract.[32]

Audiveris provides outputs in its own OMR format and the standard MusicXML format.[33] It is designed to process scores written in Common Western Music Notation (CWMN) but has limitations: it does not support handwritten scores and only recognizes common musical symbols.[34] Due to the OMR engine's accuracy not being perfect, Audiveris includes a graphical user interface (GUI) for quick verification and manual correction of the OMR outputs.[35] The MusicXML output can then be used with external sophisticated music editors like MuseScore or Finale.[36] While Audiveris is an open-source tool, explicit details regarding its direct screen reader compatibility for its GUI are not provided in the available information. However, its ability to generate MusicXML is crucial for downstream accessible tools.

Deep Learning-Based OMR (PyTorch/TensorFlow)

Recent advancements in Optical Music Recognition (OMR) have largely been driven by deep learning methods, particularly end-to-end models that process input images to produce a linear sequence of tokens.[37,38] These models are applied to various stages of OMR, including staff processing, music object detection, and music notation reconstruction.[39] Frameworks like PyTorch and TensorFlow are foundational for these general-purpose machine learning and deep learning applications.[40,41]

29 https://audiveris.org/
30 https://github.com/Audiveris/audiveris
31 https://audiveris.org/
32 https://audiveris.org/
33 https://audiveris.org/
34 https://audiveris.org/
35 https://audiveris.org/
36 https://audiveris.org/
37 https://www.researchgate.net/publication/355469493_An_Empirical_Evaluation_of_End-to-End_Polyphonic_Optical_Music_Recognition
38 https://www.researchgate.net/publication/362243760_Linearized_MusicXML_for_End-to-End_Optical_Music_Recognition
39 https://www.researchgate.net/publication/355469493_An_Empirical_Evaluation_of_End-to-End_Polyphonic_Optical_Music_Recognition
40 https://pytorch.org/
41 https://www.tensorflow.org/

One notable project is `sachindae/polyphonic-omr`, hosted on GitHub, which provides PyTorch code for end-to-end OMR on polyphonic scores.[42] This project is derived from a TensorFlow-based OMR for monophonic scores and was used in research for ”An Empirical Evaluation of End-to-End Polyphonic Optical Music Recognition” (ISMIR 2021).[43] Another example is `GaetanBaert/OMR_deep`, a deep learning OMR system that aims to recognize notes on images.[44] It utilizes a dataset derived from MuseScore (limited to monophonic scores) and employs a neural network architecture consisting of Convolutional Neural Networks (CNN) followed by Bidirectional Long-Short Term Memory (BLSTM) layers and a CTC (Connectionist Temporal Classification) model to classify note name, octave, and rhythm.[45]

A challenge in deep learning OMR, especially for complex scores like piano music, is the difficulty of converting them into a simple linear sequence, which has led researchers to develop custom linearized encodings.[46] To bridge this gap and maintain compatibility with the industry-standard MusicXML, a sequential format called Linearized MusicXML has been defined, allowing end-to-end models to be trained directly.[47] While these deep learning projects are primarily research-oriented and hosted on platforms like GitHub (which has its own accessibility initiatives[48]), explicit accessibility features for visually impaired users within the OMR tools themselves are not detailed in the provided information. Their value lies in their potential to improve the accuracy and automation of the initial OMR step, producing MusicXML that can then be processed by accessible braille transcription tools.

Manual Note Entry

Direct manual entry of musical notation is a robust alternative to OMR, offering greater control and accuracy. Several tools support this method:

- *Lime:* Integrated with GOODFEEL and Lime Aloud, Lime allows users to enter and edit scores using a PC keyboard and/or a MIDI musical keyboard. Lime can

[42] https://github.com/sachindae/polyphonic-omr
[43] https://github.com/sachindae/polyphonic-omr
[44] https://github.com/GaetanBaert/OMR_deep
[45] https://github.com/GaetanBaert/OMR_deep
[46] https://www.researchgate.net/publication/362243760_Linearized_MusicXML_for_End-to-End_Optical_Music_Recognition
[47] https://www.researchgate.net/publication/362243760_Linearized_MusicXML_for_End-to-End_Optical_Music_Recognition
[48] https://github.blog/2020-03-24-a-more-accessible-github/

automatically convert played input into conventional musical notation.[49,50,51]

- *MuseScore Studio:* This software incorporates ”basic braille music input”.[52] It utilizes a 6-key braille input method, mimicking a Perkins Brailler, where specific computer keyboard keys (F, D, S for dots 1-3; J, K, L for dots 4-6; Space for dot 0) are used to construct braille cells.[53]
- *Braille Music Notator:* This online tool is specifically designed for direct input in braille music notation. It features a braille-centric interface where braille characters are automatically translated into traditional musical symbols for visual display. It supports both keyboard input and a visual keyboard diagram.[54,55]
- *Braille Music Editor:* This program also provides an intuitive interface for creating and modifying musical compositions directly using braille notation.[56]

Digital Music Interchange: The Pivotal Role of MusicXML

MusicXML is widely recognized as a standard format used by music educators and publishers for interchanging scores between applications.[57] Its importance as a universal interoperability backbone cannot be overstated. Its widespread adoption ensures that musical data can be seamlessly exchanged between diverse notation tools and braille transcription software.

The critical role of MusicXML is underscored by its extensive support across various transcription tools for both import and export:

- *GOODFEEL:* Imports MusicXML scores.[58]
- *FreeDots:* Currently supports only MusicXML as an input format.[59]
- *BrailleMUSE:* Translates MusicXML into braille music.[60]

49 https://www.dancingdots.com/main/goodfeel.htm
50 https://canasstech.com/products/lime-aloud
51 https://www.dancingdots.com/main/prodesc/lime.htm
52 https://soundwithoutsight.org/hub-articles/using-musescore-studio-with-a-screen-reader/
53 https://musescore.org/en/handbook/4/braille
54 https://www.pathstoliteracy.org/resource/braille-music-notator/
55 https://www.braillemusicnotator.com/
56 https://braillemusiceditor.com/
57 https://www.dancingdots.com/main/goodfeel.htm
58 https://www.dancingdots.com/main/goodfeel.htm
59 https://blind.guru/projects/freedots.html
60 https://www.braillemuse.net/braille_music_score/en2/index.html

- *Braille Music Editor:* Supports import and export up to MusicXML 4.0.[61]
- *MuseScore:* Can export MusicXML, and its braille conversion plugins/web services often utilize MusicXML as an intermediary.[62]

The DAISY Consortium actively champions the creation of ”braille-conversion-friendly” MusicXML files, providing guidelines for engravers who use mainstream notation software like Sibelius, Finale, and MuseScore.[63] This concerted effort to standardize and streamline the pipeline through MusicXML highlights that the music braille ecosystem is not composed of isolated tools but rather an interconnected network where strong standards and collaborative initiatives are critical for overall accessibility. The combined utility of these tools, facilitated by MusicXML, is often greater than the sum of their individual parts.

11.4.6 Conversion and Editing Stage

Once musical data is in a digital format, it proceeds to the conversion and editing stage, where it is transformed into braille and refined for readability.

Automated Braille Translation Engines

Many tools offer automated conversion from MusicXML or other digital formats into braille:

- *GOODFEEL:* Automatically converts computer files of print scores to braille music, including MusicXML imports.[64]
- *FreeDots:* Designed to translate MusicXML files into braille music.[65]
- *BrailleMUSE:* An online server that translates MusicXML format to braille music systems.[66]
- *MusicBrailleRAP:* Uses the `music21` Python module to translate MusicXML files into braille text.[67]

61 https://braillemusiceditor.com/
62 https://musescore.org/en/accessibility
63 https://daisy.org/activities/projects/music-braille/latest-developments/
64 https://www.dancingdots.com/main/goodfeel.htm
65 https://blind.guru/projects/freedots.html
66 https://www.braillemuse.net/braille_music_score/en2/index.html
67 https://github.com/braillerap/MusicBrailleRAP

- *MakeBraille:* Supported by the DAISY Consortium, this is an online automated professional conversion tool that processes well-marked-up scanned music files and structured MusicXML files into music braille.[68]

BrailleBlaster, while primarily focused on literary and math braille transcription, utilizes Liblouis, a well-known open-source braille translator.[69] Its specific capabilities for comprehensive music score transcription from MusicXML are not explicitly detailed in the provided information, suggesting its music braille support might be more general, perhaps focused on embedding short musical examples within general texts rather than full score conversion.

Dedicated Braille Music Editing Interfaces

For nuanced control and refinement of braille music, dedicated editing interfaces are essential:

- *Braille Music Notator:* This free online tool facilitates editing directly in braille music notation. It automatically translates braille characters into traditional musical symbols for sighted users, allowing scores to be designed with the braille reader in mind for elegance and legibility.[70,71] It also supports opening and editing braille music files created in other programs.[72]
- *Braille Music Editor:* Described as offering "the most advanced braille music editing capabilities," this commercial software supports improved import/export of lyrics and fingering from MusicXML, includes standardized jazz chord symbols, and allows control of external keyboards via Midimapper.[73]
- *MuseScore Studio:* Provides "basic braille music input" and a dedicated braille panel for navigation and 6-key input, enabling users to interact with the score directly in braille.[74,75]

68 https://daisy.org/activities/projects/music-braille/latest-developments/
69 https://www.aph.org/product/brailleblaster/
70 https://www.pathstoliteracy.org/resource/braille-music-notator/
71 https://www.braillemusicnotator.com/
72 https://www.braillemusicnotator.com/
73 https://braillemusiceditor.com/
74 https://soundwithoutsight.org/hub-articles/using-musescore-studio-with-a-screen-reader/
75 https://musescore.org/en/handbook/4/braille

11.4.7 Output Stage

The final stage involves generating braille music in various formats for consumption by visually impaired musicians.

Standard Braille Formats (.brf)

The .brf format is a standard for braille files. GOODFEEL saves braille scores in the standard .brf format by default.[76] Refreshable braille displays, such as the Focus Blue, can directly read .brf files, providing immediate tactile access to the transcribed music.[77]

MusicXML for Further Processing or Interchange

Beyond braille output, some tools can export MusicXML, allowing for further processing or interchange with other music software. Braille Music Editor supports import and export up to MusicXML 4.0, ensuring compatibility with current standards.[78] MuseScore can also export MusicXML.[79] GOODFEEL enables blind musicians to independently create print scores from their musical ideas, which would typically involve MusicXML as an intermediary.[80]

11.5 BMML and XML-Based Braille Music Systems

The development of structured markup languages for braille music has emerged as a crucial advancement in making musical scores more accessible and interchangeable. This section examines BMML (Braille Music Markup Language) and associated tools that leverage XML-based approaches to braille music representation, storage, and manipulation.

11.5.1 BMML: Braille Music Markup Language

BMML represents a significant advancement in braille music technology, designed to address the fundamental challenge that *braille musicography is a notation for music*

76 `https://www.dancingdots.com/main/goodfeel.htm`
77 `https://www.aph.org/product/focus-blue-5th-generation-braille-displays/`
78 `https://braillemusiceditor.com/`
79 `https://musescore.org/en/accessibility`
80 `https://www.dancingdots.com/main/goodfeel.htm`

based on Braille code. It is a very useful tool for blind musicians, but it is more difficult to read and write than conventional music notation due to its linear nature compared to the bidimensional structure of traditional notation.

Technical Foundation

BMML is built on XML standards to provide a structured format for braille music scores. The BMML (Braille Music Mark-up Language) format, based on XML, aims at coding musical scores into Braille and complies with the NIM standards (New International Manual of Braille Music Notation). This XML-based approach enables standardized representation and exchange of braille music content across different platforms and applications.

Research Background

The development of BMML emerged from academic research recognizing that for specific notations – like the Braille one - no dedicated XML application has been developed yet. Therefore, visually impaired musicians cannot easily represent, share, and access scores using the Web. The research focused on creating a markup language that handles specificities of Braille Music notation and takes into account the core features of existing formats to improve the accessibility of Braille musical scores.

Key Features

BMML addresses several critical needs in braille music technology:

- **Web Accessibility Integration:** Thanks to the WAI (Web Accessibility Initiative) guidelines for producing accessible HTML documents, visually impaired people can have better access to a lot of textual information, and BMML extends this accessibility to musical content.
- **Structured Data Representation:** Unlike traditional braille music files that are archived or shared as text files, with only character information dependent on some translation table, BMML provides structured, contextual information about musical elements.
- **Interoperability:** The XML foundation enables integration with existing music notation software and web-based distribution systems.

11.5.2 The Contrapunctus Project

The Contrapunctus project represents a significant European initiative in advancing braille music technology. Contrapunctus is an European research project, started on 1st June 2006 and ended on 31st May 2009. Its main goal is to design and to develop a demonstrative service allowing blind musicians a faster and easier access and use of the Braille music scores, filed in libraries and transcription centers.

Project Objectives

The project addressed the critical need for a uniform format for Braille musical scores by developing BMML as a standardized markup language. This initiative recognized that existing braille music distribution methods were inadequate for the digital age and modern accessibility requirements.

Braille Music Reader

A key output of the Contrapunctus project was the development of the Braille Music Reader, a specialized application designed to work with BMML files. The Braille Music Reader can import a Braille music score in BMML (Braille Music XML) format, and explore it under any aspect. In this way, the visually impaired user is supplied with a tool that allows a very easy reading and that is much more functional to his study than the tactile reading of the text printed on paper.

The reader provides enhanced functionality beyond traditional braille music files: The great news introduced by Contrapunctus project is that the music score, opened by the Braille Music Reader, will not only be a simple ASCII document to be read through the screen reader and/or the Braille line. Instead, it will be a file containing the contextualized musical elements.

11.5.3 BME2 and BM2021: Advanced Braille Music Editors

Building upon the foundation established by BMML research, several commercial applications have emerged that incorporate XML-based approaches to braille music editing and production.

BME2 (Braille Music Editor 2)

Developed by Veia progetti, BME2 represents a comprehensive braille music editing solution. BME2, Braille Music Editor 2, is a new and extraordinary tool allowing blind musicians (amateurs or professionals) to write music scores, to check, to correct, to print or to emboss them all by themselves. Music writing follows the rules of the New International Manual of Braille Music Notation.

Key Features:

- **Multi-Modal Verification:** The music score can be checked in various ways, through the screen-reader speech output pronouncing musical elements, through the MIDI sound or on the Braille display.
- **Export Capabilities:** Once the score is complete, it can be exported in MusicXML and visualised with Finale, Sibelius or lots of other programs.
- **Professional Integration:** The software bridges the gap between braille music creation and mainstream music notation software.

BM2021 (Braille Music 2021)

BM2021 represents an evolution of the BME2 platform, maintaining the same core functionality while incorporating updated features and improved accessibility. Like its predecessor, it follows the New International Manual of Braille Music Notation standards and provides comprehensive score creation, verification, and export capabilities.

Braille Music Editor 2025

The latest iteration of this software line, Braille Music Editor 2025, continues to advance the field with enhanced features and improved compatibility with modern operating systems and assistive technologies.

Licensing and Accessibility:

- Commercial software with single installation. 350 Euro! BUY NOW Braille Music Editor 2025 with dual installation. 550 Euro!
- Free Bm2025 script for JAWS compatible with Windows 10 and 11
- Screen reader compatibility and specialized add-ons for enhanced accessibility

11.5.4 Integration with Mainstream Music Technology

The BMML ecosystem demonstrates successful integration with established music technology standards. The ability to export to MusicXML and visualised with Finale, Sibelius or lots of other programs creates a bidirectional workflow where braille music can be created, edited, and shared with sighted musicians and music publishers.

This integration addresses historical challenges where braille music existed in isolation from mainstream music production workflows. By leveraging XML-based standards, these tools enable collaborative music creation and distribution that includes both braille and print music users.

11.5.5 Technical Advantages of XML-Based Approaches

The XML foundation of BMML and related systems provides several technical advantages:

- **Structured Data:** Unlike simple text representations, XML enables semantic markup of musical elements, facilitating more sophisticated processing and analysis.
- **Standardization:** XML-based formats can be validated against schemas, ensuring consistency and compatibility across different tools and platforms.
- **Extensibility:** The XML framework allows for future enhancements and specialized extensions while maintaining backward compatibility.
- **Web Integration:** XML formats integrate naturally with web-based distribution systems and accessibility frameworks.

11.5.6 Future Directions and Research

The success of BMML and related systems has established a foundation for continued development in braille music technology. Research continues in areas such as automated translation between braille and print music formats, enhanced accessibility features for diverse user needs, and integration with emerging music technologies such as digital audio workstations and computer-aided composition tools.

The establishment of standardized XML-based formats like BMML represents a crucial step toward universal accessibility in music technology, enabling blind and visually impaired musicians to participate more fully in all aspects of musical creation, performance, and education.

Direct Output to Embossers and Refreshable Braille Displays

For physical braille output, software often interfaces directly with braille embossers. Duxbury Braille Translator (DBT) supports output to all commercial braille embossers, accommodating a wide range of models, from very old to recent ones.[81] MusicBrailleRAP is specifically designed to produce braille text ”ready to emboss on a BrailleRAP” device.[82]

For real-time tactile reading, refreshable braille displays are crucial. Devices like the Focus Blue can connect to Windows, Apple, or Android devices running screen readers (e.g., JAWS, VoiceOver) to provide tactile braille access to content.[83,84] These displays can also read .brf and plain text files directly.[85] Braille Music Editor includes a script for managing the six points on the Braille line of the Focus display, indicating specific integration for enhanced tactile interaction.[86]

Accessibility Integration Across the Pipeline

Accessibility is a paramount consideration throughout the music braille generation pipeline, with various features designed to support visually impaired users.

Screen Reader Compatibility

Many tools are designed to work seamlessly with screen readers, which convert on-screen text and elements into speech or braille:

- **MuseScore:** Compatible with NVDA (NonVisual Desktop Access).[87,88,89] MuseScore 4 also includes support for VoiceOver on macOS.[90]
- **GOODFEEL:** Its integrated Lime Aloud talking score feature works with JAWS for Windows (versions 15 through current) and is also compatible with non-JAWS

---

81 https://www.duxburysystems.com/dbt.asp
82 https://github.com/braillerap/MusicBrailleRAP
83 https://www.aph.org/product/focus-blue-5th-generation-braille-displays/
84 https://www.freedomscientific.com/products/software/jaws/
85 https://www.aph.org/product/focus-blue-5th-generation-braille-displays/
86 https://braillemusiceditor.com/
87 https://soundwithoutsight.org/hub-articles/using-musescore-studio-with-a-screen-reader/
88 https://musescore.org/en/handbook/4/accessibility
89 https://musescore.org/en/handbook/4/accessibility
90 https://daisy.org/activities/projects/music-braille/latest-developments/

screen readers such as NVDA and Narrator.[91,92]

- **Braille Music Notator:** Adheres to WAI-ARIA standards for accessible web applications and is compatible with major screen reading software like JAWS and VoiceOver.[93]
- **Braille Music Editor:** Offers a free JAWS script specifically for Windows 10 and 11 users.[94]
- **MusicBrailleRAP:** Explicitly stated as NVDA compatible.[95]
- **Duxbury Braille Translator (DBT):** Described as "fully accessible" and compatible with modern operating systems and applications for both blind and sighted users.[96]
- **KNFB Reader:** While a general text-to-speech/braille app, it demonstrates core accessibility principles for print-disabled users across mobile platforms.[97]

Keyboard Navigation

Efficient keyboard navigation is crucial for blind users who do not rely on a mouse. MuseScore provides a wide array of keyboard shortcuts for efficient task execution.[98,99] Notably, MuseScore 4's navigation relies on arrow keys in addition to the tab key for cycling through control groups and individual controls.[100] Braille Music Notator also supports arrow keys, return, and home keys for cursor navigation within the braille score.[101]

Audio Descriptions/Feedback

Auditory feedback enhances the user experience by providing spoken information about musical elements:

[91] https://www.dancingdots.com/main/goodfeel.htm
[92] https://canasstech.com/products/lime-aloud
[93] https://www.braillemusicnotator.com/
[94] https://braillemusiceditor.com/
[95] https://github.com/braillerap/MusicBrailleRAP
[96] https://www.duxburysystems.com/dbt_brochure.asp
[97] https://www.knfbreader.com/
[98] https://musescore.org/en/handbook/4/accessibility
[99] https://musescore.org/en/handbook/4/braille
[100] https://musescore.org/en/accessibility
[101] https://www.braillemusicnotator.com/quick-start-screen-reader-users

- **MuseScore:** Includes audio descriptions of sheet music elements, allowing screen readers to provide detailed information about notes, chords, and dynamics.[102] It also plays the sound of a note when it is selected in the braille panel.[103]
- **GOODFEEL/Lime Aloud:** Plays each note or chord and verbally describes associated annotations (e.g., accents, staccato marks, lyrics, ties) via the JAWS screen reader.[104,105] Users have the option to speak lyric syllables and chords during playback[106] and can temporarily mute verbal descriptions with a "Silenzio" mode for focused listening.[107]
- **Refreshable Braille Displays:** When used with screen readers like JAWS, these displays can announce current braille characters or spell out words in "Braille Study Mode".[108]

Synchronized Playback

A particularly valuable accessibility feature for learning and proofreading is synchronized playback. GOODFEEL offers this capability, where braille and print music track in sync with audio cues, provided JAWS and a braille display are used.[109] This allows users to follow the music tactilely, visually (for sighted collaborators or low-vision users), and audibly simultaneously.

11.6 Open-Source and GitHub-Hosted Solutions for Music Braille Transcription

Open-source projects offer cost-free access and the potential for community-driven development, making them vital components of the accessible music braille ecosystem.

[102] https://musescore.org/en/handbook/4/accessibility
[103] https://musescore.org/en/handbook/4/braille
[104] https://www.dancingdots.com/main/goodfeel.htm
[105] https://canasstech.com/products/lime-aloud
[106] https://www.dancingdots.com/main/goodfeel.htm
[107] https://www.dancingdots.com/main/goodfeel.htm
[108] https://www.aph.org/product/focus-blue-5th-generation-braille-displays/
[109] https://www.dancingdots.com/main/goodfeel.htm

11.6.1 BrailleBlaster (APH)

Developed by the American Printing House for the Blind (APH), BrailleBlaster is a free and open-source braille transcription program.[110,111,112] Its primary focus is on producing high-quality braille materials, especially textbooks, by leveraging rich markup in files like NIMAS, EPUB, and DOCX to automate translation and formatting.[113] The software relies on Liblouis, a widely recognized open-source braille translator, for handling text and mathematics.[114] BrailleBlaster-NG is a community-enhanced fork, aiming to be responsive to community needs and contributions.[115]

While Duxbury DBT, which can import from GOODFEEL, mentions "extensive math, science and music code support" in relation to general braille software[116], the core BrailleBlaster documentation primarily emphasizes literary and math braille transcription.[117,118] There is no explicit mention of MusicXML import for full music notation or specific music braille features beyond general "music code support." This suggests its music braille capabilities might be more general, perhaps focused on embedding short musical examples within literary texts rather than comprehensive score transcription. BrailleBlaster is designed to help braille producers ensure timely access to educational materials for blind individuals and supports Windows, Mac OS X, and Ubuntu Linux.[119,120]

11.6.2 MusicBrailleRAP

MusicBrailleRAP is music score transcription software specifically designed for BrailleRAP devices, with its source code hosted on GitHub.[121] It utilizes the `music21` Python module to translate MusicXML files into braille text, which is then prepared for embossing on a BrailleRAP device.[122] The project also incorporates `liblouisreact`, a modified version of `liblouis` adapted for a React.js environment.[123] It is noted that the

[110] https://github.com/aphtech/brailleblaster-ng
[111] https://www.aph.org/product/brailleblaster/
[112] https://github.com/aphtech/brailleblaster
[113] https://www.aph.org/product/brailleblaster/
[114] https://www.aph.org/product/brailleblaster/
[115] https://github.com/aphtech/brailleblaster-ng
[116] https://www.duxburysystems.com/dbt.asp
[117] https://github.com/aphtech/brailleblaster-ng
[118] https://www.aph.org/product/brailleblaster/
[119] https://github.com/aphtech/brailleblaster-ng
[120] https://www.aph.org/product/brailleblaster/
[121] https://github.com/braillerap/MusicBrailleRAP
[122] https://github.com/braillerap/MusicBrailleRAP
[123] https://github.com/braillerap/MusicBrailleRAP

project is ”still a work in progress”.[124] Its input is MusicXML, and its output is braille text for BrailleRAP embossing; specific braille output formats beyond ”Braille text” are not detailed.[125] The software is compatible with NVDA (NonVisual Desktop Access), indicating a focus on accessibility for visually impaired users.[126]

11.6.3 FreeDots

FreeDots is a Free Software project hosted on GitHub, dedicated to translating musical notation into braille music for blind users.[127] Currently, the only supported input file format is MusicXML.[128] It features a graphical user interface (GUI) frontend for viewing braille music, with future plans to support editing.[129] The project is described as ”very young,” with many braille music notation features not yet implemented and an incomplete user manual.[130] Its core mission is to enable blind users to access musical notation[131], though specific details regarding the GUI's accessibility features (e.g., screen reader compatibility) are not specified.[132]

11.6.4 MuseScore

MuseScore is a popular, free, and widely used music notation software that enables musicians globally to create, play, and share musical scores.[133,134] It allows users to write notation, explore, and play existing digital scores on Windows and Mac operating systems.[135]

124 https://github.com/braillerap/MusicBrailleRAP
125 https://github.com/braillerap/MusicBrailleRAP
126 https://github.com/braillerap/MusicBrailleRAP
127 https://blind.guru/projects/freedots.html
128 https://blind.guru/projects/freedots.html
129 https://blind.guru/projects/freedots.html
130 https://blind.guru/projects/freedots.html
131 https://blind.guru/projects/freedots.html
132 https://blind.guru/projects/freedots.html
133 https://soundwithoutsight.org/hub-articles/using-musescore-studio-with-a-screen-reader/
134 https://musescore.org/en/handbook/4/accessibility
135 https://soundwithoutsight.org/hub-articles/using-musescore-studio-with-a-screen-reader/

Braille Music Capabilities

The latest version, MuseScore Studio, includes "basic braille music input" capabilities.[136] MuseScore 4 offers a native ability to export braille via its File > Export function.[137] For users of MuseScore 3, the SM Music Braille plugin, which utilizes a free web service from the Sao Mai Center for the Blind, can convert scores to Music Braille. It is noted that this web service often yields better results than MuseScore 4's native export.[138] MuseScore provides a dedicated braille panel for navigation and supports a 6-key braille input method, similar to a Perkins Brailler, using specific computer keyboard keys (F, D, S for dots 1-3; J, K, L for dots 4-6; Space for dot 0).[139] The braille panel displays one measure at a time for all instruments, with lyrics appearing on separate lines below their corresponding staff.[140] New music braille capabilities are actively being developed for MuseScore 4 in partnership with the DAISY Consortium and Sao Mai Center for the Blind.[141]

Accessibility Features

MuseScore is highly committed to accessibility:

- **Screen Reader Compatibility:** It is compatible with NVDA (NonVisual Desktop Access).[142,143] MuseScore 4 also includes support for VoiceOver on macOS.[144]
- **Keyboard Shortcuts:** It offers a wide range of keyboard shortcuts, which are crucial for efficient navigation and task execution by blind users without a mouse.[145,146]
- **Audio Descriptions:** MuseScore provides audio descriptions of sheet music elements, allowing the screen reader to convey detailed information about notes, chords, and dynamics.[147] It also plays the sound of a note when it is selected in the

[136] https://soundwithoutsight.org/hub-articles/using-musescore-studio-with-a-screen-reader/
[137] https://musescore.org/en/accessibility
[138] https://musescore.org/en/accessibility
[139] https://musescore.org/en/handbook/4/braille
[140] https://musescore.org/en/handbook/4/braille
[141] https://daisy.org/activities/projects/music-braille/latest-developments/
[142] https://soundwithoutsight.org/hub-articles/using-musescore-studio-with-a-screen-reader/
[143] https://musescore.org/en/handbook/4/accessibility
[144] https://daisy.org/activities/projects/music-braille/latest-developments/
[145] https://musescore.org/en/accessibility
[146] https://musescore.org/en/handbook/4/braille
[147] https://musescore.org/en/handbook/4/accessibility

braille panel.[148]

- **Accessibility Guide:** A detailed accessibility guide is available on the MuseScore website, offering step-by-step instructions and practical tips for blind users.[149,150]

OMR Potential

MuseScore has an OMR development branch that currently recognizes staves and barlines.[151] The long-term goal is to recognize all symbols simultaneously to significantly improve accuracy.[152]

11.6.5 Table 1: Overview of Open-Source Music Braille Transcription Software

Table 11.1: Overview of Open-Source Music Braille Transcription So

Software Name	Developer/Host	Primary Focus	Music Braille Input	Music Braille Output	Key Ac Features
Audiveris	Audiveris.org / GitHub (`Audiveris/audiveris`)	Optical Music Recognition (OMR)	Scanned images/photos of print music	MusicXML, Audiveris OMR format	GUI for correction; MusicXML for a downstrea
Deep Learning OMR (e.g., `sachindae/polyphonic-omr`, `GaetanBaert/OMR_deep`)	GitHub	Research-oriented OMR for MusicXML generation	Image of music score	Linearized MusicXML	Primarily tools; MusicXML accessible

148 `https://musescore.org/en/handbook/4/braille`
149 `https://soundwithoutsight.org/hub-articles/using-musescore-studio-with-a-screen-reader/`
150 `https://musescore.org/en/accessibility`
151 `https://musescore.org/en/node/110306`
152 `https://musescore.org/en/node/110306`

Table 11.1: Overview of Open-Source Music Braille Transcription Software (Conti

Software Name	Developer/Host	Primary Focus	Music Braille Input	Music Braille Output	Key Accessibil Features
BrailleBlaster	APH (aphtech/brailleblaster)	General braille transcription (textbooks, literary, math)	NIMAS, EPUB, DOCX (general text); limited music code support	UEB, EBAE braille	Designed f accessibility, supports Window Mac, Linux
MusicBrailleRAP	braillerap/MusicBrailleRAP	Score transcription for BrailleRAP embossers	MusicXML[179]	Braille text for BrailleRAP embossing[180]	NVDA compatible[1
FreeDots	mlang/FreeDots (blind.guru)	MusicXML to Braille Music translation	MusicXML[184]	Braille music (viewable via GUI)[185]	Designed f blind users; G frontend[186]
MuseScore	MuseScore.org	General music notation software	Manual (6-key braille, PC/MIDI keyboard), MusicXML import	MusicXML, Native Braille Export, SM Music Braille Plugin output	NVDA/VoiceOver compatible, extensive keyboa shortcuts, auc descriptions, accessibility guide[189,190,191]

Many open-source projects, while promising and community-driven, are still in early development stages with known limitations. For instance, FreeDots is described as a "very young project" with "many braille music notation features not yet implemented" and an "incomplete user manual".[195] Similarly, MusicBrailleRAP is explicitly noted as "still a work in progress project".[196] This indicates that while open-source solutions offer cost-free access and the potential for customization, they may not yet provide the comprehensive, polished experience of commercial alternatives. Users considering these tools should be prepared for potential bugs or missing features.

195 `https://blind.guru/projects/freedots.html`
196 `https://github.com/braillerap/MusicBrailleRAP`

There is a discernible trade-off in open-source tools between specialization and generalization. Some tools are highly specialized for music braille, such as MusicBrailleRAP, which is tailored for specific BrailleRAP devices[197], or FreeDots, which focuses solely on MusicXML to braille music translation.[198] In contrast, BrailleBlaster is a general-purpose braille translator primarily for textbooks, with its ”music code support” being a broader feature rather than a dedicated music score transcriber.[199] MuseScore stands out as a general music notation tool that has increasingly integrated robust music braille capabilities, offering a hybrid approach. This means users seeking a dedicated, ”braille-first” experience for music might look to highly specialized open-source tools, while those needing a broader music notation environment with integrated braille capabilities would gravitate towards MuseScore, which offers a more comprehensive, yet still free, solution.

11.7 Commercial Software Solutions for Music Braille Transcription

Commercial software typically offers more polished features, dedicated customer support, and often a more integrated user experience, appealing to professional transcribers and institutions.

11.7.1 GOODFEEL Braille Music Translator (Dancing Dots)

Developed by Dancing Dots, GOODFEEL is a comprehensive software suite designed to enable sighted musicians to quickly and accurately convert print scores to braille music. It also empowers blind musicians to review braille scores and independently create print scores of their musical ideas.[200,201]

Input

GOODFEEL supports scanning print scores, though it explicitly requires sighted musicians to correct any errors introduced during the scanning process.[202] Crucially, it

197 https://github.com/braillerap/MusicBrailleRAP
198 https://blind.guru/projects/freedots.html
199 https://www.aph.org/product/brailleblaster/
200 https://www.dancingdots.com/main/goodfeel.htm
201 https://www.dancingdots.com/main/products.htm
202 https://www.dancingdots.com/main/goodfeel.htm

allows the import of MusicXML scores created in mainstream notation software like Finale and Sibelius.[203] Scores can also be entered and edited using Lime, an integrated notation editor, with a PC keyboard and/or a MIDI musical keyboard.[204,205,206]

Output

The software produces braille music scores in the standard .brf format by default.[207] It can also generate print scores in standard staff notation for sighted readers and supports direct embossing of formatted braille music.[208] Additionally, MIDI files can be transcribed.[209]

Key Features

- Supports Unified English Braille (UEB) for transcribing text elements such as titles and lyrics within scores.[210]
- Includes integrated literary braille translation for most Western languages, enabling the brailling of both words and music.[211]
- Can be configured to conform to UK braille music production formatting conventions.[212]
- Offers a user-friendly interface for customizing braille music output.[213]
- Provides optional integration with the Duxbury (literary) Braille Translator to facilitate the transcription of theory or method books containing large blocks of expository text.[214]

203 https://www.dancingdots.com/main/goodfeel.htm
204 https://www.dancingdots.com/main/goodfeel.htm
205 https://canasstech.com/products/lime-aloud
206 https://www.dancingdots.com/main/prodesc/lime.htm
207 https://www.dancingdots.com/main/goodfeel.htm
208 https://www.dancingdots.com/main/goodfeel.htm
209 https://www.dancingdots.com/main/goodfeel.htm
210 https://www.dancingdots.com/main/goodfeel.htm
211 https://www.dancingdots.com/main/goodfeel.htm
212 https://www.dancingdots.com/main/goodfeel.htm
213 https://www.dancingdots.com/main/goodfeel.htm
214 https://www.dancingdots.com/main/goodfeel.htm

Accessibility

GOODFEEL offers extensive accessibility features:

- **Screen Reader Compatibility:** Its Lime Aloud talking score feature works seamlessly with JAWS for Windows (versions 15 through current) and is also compatible with non-JAWS screen readers such as NVDA and Narrator.[215,216]
- **Audio Feedback:** Offers optional verbal and musical cues during playback.[217] There is an option to speak lyric syllables and chords, and a ”Silenzio” mode to temporarily mute verbal descriptions for focused listening.[218]
- **Synchronized Playback:** A key feature for learning and proofreading is the ability for braille and print music to track in sync during playback from Lime’s Hear dialog, requiring JAWS and a braille display.[219]
- **Low Vision Support:** An optional add-on, Lime Lighter, provides special scrolling and magnification features for users with low vision, allowing them to mix speech and braille cues with magnified print.[220,221]
- Improved responsiveness with JAWS and other screen readers compared to previous versions.[222]

Licensing

GOODFEEL is available as a perpetual license, with an option to subscribe annually for a lower initial cost.[223] A 15-day free trial is offered.[224]

215 https://www.dancingdots.com/main/goodfeel.htm
216 https://canasstech.com/products/lime-aloud
217 https://www.dancingdots.com/main/goodfeel.htm
218 https://www.dancingdots.com/main/goodfeel.htm
219 https://www.dancingdots.com/main/goodfeel.htm
220 https://www.dancingdots.com/main/goodfeel.htm
221 https://www.dancingdots.com/main/products.htm
222 https://www.dancingdots.com/main/goodfeel.htm
223 https://www.dancingdots.com/main/goodfeel.htm
224 https://www.dancingdots.com/main/goodfeel.htm

11.7.2 Duxbury Braille Translator (DBT)

Produced by Duxbury Systems since 1975, DBT is widely recognized as a leading software for producing braille globally.[225,226,227]

Primary Focus

DBT's core strength lies in general braille translation for a wide array of documents, including Microsoft Word, Open Office, HTML, DAISY, and NIMAS files. It is extensively used for textbooks, office memos, and personal letters.[228] It supports over 180 languages and variations, including contracted braille for most regions.[229,230]

Music Braille Capabilities

DBT is stated to have "extensive math, science and music code support".[231] It can import files from the GOODFEEL Music Translation program.[232] However, the provided information does not explicitly detail its direct capability to transcribe music braille from sheet music or MusicXML *within DBT itself*.[233] This suggests its music code support is more geared towards embedding musical examples within literary braille documents or handling specific braille music codes as part of a broader braille translation, rather than being a dedicated music score converter. The observation that DBT can import files *from* GOODFEEL implies that direct MusicXML to music braille conversion isn't its primary or direct function, but rather it can process braille music *generated by other tools*.[234] This is a crucial distinction for users seeking a direct sheet music-to-braille solution, as it highlights that "music code support" in a general translator may not fulfill the needs of comprehensive music score transcription.

225 https://www.duxburysystems.com/dbt.asp
226 https://www.duxburysystems.com/dbt_brochure.asp
227 https://www.duxburysystems.com/
228 https://www.duxburysystems.com/dbt_brochure.asp
229 https://www.duxburysystems.com/dbt.asp
230 https://www.duxburysystems.com/dbt_brochure.asp
231 https://www.duxburysystems.com/dbt.asp
232 https://www.duxburysystems.com/dbt_brochure.asp
233 https://www.duxburysystems.com/dbt.asp
234 https://www.duxburysystems.com/dbt_brochure.asp

Input/Output

DBT imports numerous document formats.[235] It supports output to all commercial braille embossers, covering a wide range of models.[236] A useful feature is built-in interline printing, which displays ink text alongside braille for easier proofing and teaching.[237]

Accessibility

DBT is designed to be ”fully accessible AND fully in tune with the latest advances in operating systems and sister applications” for both blind and sighted users.[238] It is Section 508 compliant[239] and allows displaying ink text alongside braille for simplified proofreading.[240]

Licensing

DBT is a commercial product, priced at $695.00 for a perpetual license.[241] A 30-day demo software is available.[242]

---

235 https://www.duxburysystems.com/dbt_brochure.asp
236 https://www.duxburysystems.com/dbt.asp
237 https://www.duxburysystems.com/dbt_brochure.asp
238 https://www.duxburysystems.com/dbt_brochure.asp
239 https://www.duxburysystems.com/dbt.asp
240 https://www.duxburysystems.com/dbt.asp
241 https://www.duxburysystems.com/dbt.asp
242 https://www.duxburysystems.com/dbt.asp

11.7.3 Table 2: Overview of Commercial Music Braille Transcription Software

Table 11.2: Overview of Commercial Music Braille Transcription Softw

Software Name	**Developer**	**Primary Focus**	**Music Braille Input**	**Music Braille Output**	**Key Accessi Features**
GOODFEEL Braille Music Translator	Dancing Dots	Comprehensive music braille conversion and editing	Scanned print (sighted correction), MusicXML, Manual (via Lime/MIDI)[255]	.brf, Print notation, Embossed braille, MIDI[256]	JAWS/NVDA/Na compatible, a cues, synchro playback, low v add-on (Lighter), UE formatting[257]
Duxbury Braille Translator (DBT)	Duxbury Systems	General braille translation for diverse documents	MS Word, Open Office, HTML, DAISY, NIMAS, can import from GOODFEEL[261]	General braille (various codes), Embossed braille, Interline print/braille[262]	Fully acces (blind/sighted), Section compliant, text/braille di for proofing[263,2

Commercial software like GOODFEEL provides a highly integrated and polished experience, often bundling multiple functionalities such as a notation editor, OCR, and advanced braille translation and accessibility features into a single, cohesive suite.[267,268] This contrasts with open-source solutions that might require combining multiple distinct tools, offering a more streamlined workflow for professional use. This integrated approach can be particularly appealing to professional transcribers, educational institutions, or production facilities seeking a comprehensive, well-supported, and reliable solution with minimal integration overhead.

[267] `https://www.dancingdots.com/main/goodfeel.htm`
[268] `https://canasstech.com/products/lime-aloud`

11.8 Dedicated Braille Music Editors: Direct Braille Input and Refinement

Beyond automated translation, dedicated braille music editors allow for direct input and meticulous refinement of braille scores, often prioritizing the unique tactile reading experience.

11.8.1 Braille Music Notator

Braille Music Notator is a free online tool specifically designed for creating braille music scores.[269,270]

Braille-Centric Design

A core philosophy of this tool is that the entire process of creating or editing a score is done directly in braille music notation. The braille characters are then automatically translated into traditional musical symbols for visual display, allowing the score to be designed with the braille reader's needs paramount. This approach aims for ”elegant, legible scores which promote sight-reading and accuracy”.[271,272] This contrasts with tools that primarily translate print notation to braille, which often result in unpolished or inaccurate translations that do not fully account for the nuances of tactile reading.[273,274]

Input

The input method involves using braille music notation via a keyboard diagram and corresponding keys for musical symbols. It also includes a text keyboard for entering literary braille characters. The tool supports saving scores to local disk and opening/editing braille music files created in other programs.[275,276]

[269] https://www.pathstoliteracy.org/resource/braille-music-notator/
[270] https://www.braillemusicnotator.com/
[271] https://www.pathstoliteracy.org/resource/braille-music-notator/
[272] https://www.braillemusicnotator.com/
[273] https://www.pathstoliteracy.org/resource/braille-music-notator/
[274] https://www.braillemusicnotator.com/
[275] https://www.braillemusicnotator.com/
[276] https://www.braillemusicnotator.com/quick-start-screen-reader-users

Accessibility

Braille Music Notator meets WAI-ARIA standards for accessible web applications and is compatible with major screen reading software such as JAWS and VoiceOver.[277] It provides a "Quick Start for Screen Reader Users" guide to facilitate adoption by visually impaired individuals.[278]

Target Audience

While its primary goal is to produce high-quality scores for musicians who rely on braille, the utility is also designed for sighted musicians, teachers, and engravers. A secondary goal is to help sighted people learn braille music notation, fostering a "meet halfway" approach between visually impaired and sighted musicians.[279,280]

11.8.2 Braille Music Editor

Braille Music Editor (e.g., Braille Music Editor 2025) is a commercial software offering advanced capabilities for creating and modifying music compositions using braille notation.[281]

Key Features

- Includes a script for managing the six points on the Braille line of the Focus refreshable braille display, indicating deep integration with tactile output devices for precise control over braille cells.[282]
- Offers improved import and export functionalities for lyrics and fingering from MusicXML files, ensuring compatibility with other notation software.[283]
- Standardized 140 jazz chord symbols in Braille, based on The New Real Book and the Finale and Sibelius libraries, providing a comprehensive set for contemporary music.[284]

277 https://www.braillemusicnotator.com/
278 https://www.braillemusicnotator.com/
279 https://www.pathstoliteracy.org/resource/braille-music-notator/
280 https://www.braillemusicnotator.com/
281 https://braillemusiceditor.com/
282 https://braillemusiceditor.com/
283 https://braillemusiceditor.com/
284 https://braillemusiceditor.com/

- Allows control of external keyboards via Midimapper, enhancing input flexibility for musicians.[285]
- Revised pause management to support anacrustic and acephalous pieces, addressing complex rhythmic structures.[286]
- Added new options for handling MIDI parameters, providing granular control over musical performance data.[287]

Accessibility

The program provides an intuitive and user-friendly interface for creating and modifying music compositions utilizing braille notation.[288] A free Bm2025 script for JAWS is available for download, compatible with Windows 10 and 11, ensuring robust screen reader support.[289] The *Giuseppe Paccini Association*, a partner in the European *Erasmus+ MUVIE* project, is actively involved in transforming music education for the visually impaired through technology, including the creation of accessible digital tools, cutting-edge methodologies, and a Braille music library, demonstrating a commitment to broader accessibility initiatives.[290]

11.9 Conclusions

The landscape of accessible music braille transcription is a multifaceted domain, driven by both technological innovation and a profound dedication to inclusivity. The analysis reveals a dual approach to braille music production: automated translation from digital notation (primarily MusicXML) for efficiency, and direct braille-centric input/editing for tactile readability and nuanced control. This duality underscores the understanding that a direct one-to-one conversion from print notation often falls short of producing truly optimal braille for the visually impaired musician, necessitating tools that prioritize the unique characteristics of braille music.

MusicXML stands as the indispensable backbone of this ecosystem, serving as the universal standard for digital music interchange. Its widespread adoption by mainstream notation software is critical for facilitating seamless data flow between diverse tools,

285 https://braillemusiceditor.com/
286 https://braillemusiceditor.com/
287 https://braillemusiceditor.com/
288 https://braillemusiceditor.com/
289 https://braillemusiceditor.com/
290 https://braillemusiceditor.com/

making it the most reliable input format for automated braille conversion. Without this standardized intermediary, the interoperability required for a comprehensive and efficient transcription pipeline would be severely compromised.

A significant portion of the advancements in accessible music braille tools, particularly within the open-source realm, is powered by collaborative community efforts and non-profit initiatives. This collective drive fills crucial gaps that commercial ventures might not address, fostering a vibrant environment for innovation and development. However, it is important to acknowledge that many open-source projects are still in nascent stages, with known limitations and ongoing development. This implies that while they offer accessible, cost-free solutions, they may not yet provide the comprehensive and polished experience found in more mature commercial offerings.

Commercial solutions, exemplified by GOODFEEL, typically offer a highly integrated and refined user experience, often bundling multiple functionalities into a cohesive suite. This integrated approach can streamline workflows for professional transcribers and institutions, providing a robust and well-supported environment. Conversely, general braille translators like Duxbury Braille Translator, while possessing ”music code support,” are primarily designed for literary braille and may not offer the direct, comprehensive music score transcription capabilities from MusicXML that dedicated music braille software provides. This distinction is crucial for users to understand when selecting tools for specific music transcription needs.

Finally, the inherent cognitive load of reading braille music, stemming from its linear nature and significant space requirements, necessitates that transcription tools go beyond mere accuracy. Features such as synchronized playback, audio descriptions, and intuitive braille-centric editing interfaces are not merely enhancements but essential components that support learning, memorization, and performance for visually impaired musicians. The continuous development and integration of these accessibility features across the entire pipeline are paramount to ensuring that visually impaired musicians can engage with music on an equal footing with their sighted peers, fostering independence and creative expression.

Chapter 12

Computer Specifications and Embosser Compatibility for Tactile Graphics Software

12.1 Executive Summary

This report provides an overview of software solutions for generating tactile graphics for individuals who are blind or visually impaired, covering Windows, MacOS, and Linux operating systems. It includes commercial and open-source applications, detailing their computer specifications, embosser compatibility, and limitations.

Commercial tactile graphics software is predominantly centered on Windows platforms, with MacOS users often requiring Windows emulators. Linux supports some open-source vector graphics editors but has fewer dedicated tactile graphics applications. Hardware requirements are generally moderate, with increased RAM enhancing performance for complex design tasks.

Embosser compatibility varies widely. Some programs support multiple embosser brands, while others are integrated with specific ecosystems. The adoption of Scalable Vector Graphics (SVG) as an intermediate file format facilitates interoperability between design tools and tactile output devices.

The report categorizes software into specialized tools for tactile graphic creation and general-purpose software adaptable for tactile output. The choice depends on user needs, technical proficiency, and the required tactile output type.

12.2 Introduction to Tactile Graphics Technology

12.2.1 The Role of Tactile Graphics for the Visually Impaired

Tactile graphics are specialized images designed to be interpreted through touch, providing critical non-textual information to individuals who are blind or have low vision. These graphics encompass a wide array of visual data, including pictures, diagrams, maps, and graphs. Their importance cannot be overstated, as they serve as essential tools for orientation, route planning, educational attainment, and fostering greater independence and inclusion in a visually-dominated world. By converting visual information into raised lines, textures, and patterns, tactile graphics enable visually impaired individuals to access and comprehend spatial relationships, abstract concepts, and complex data that would otherwise be inaccessible.[1]

12.2.2 Overview of Software Categories for Tactile Production

The ecosystem of software for tactile graphics production is diverse, comprising several distinct categories. Dedicated tactile design tools are purpose-built for creating and editing tactile content, often featuring specialized functions for braille labeling and multi-dot height embossing. Braille translation software frequently includes integrated graphics capabilities, allowing for the combination of braille text with tactile images within a single document. Specialized map generators focus on creating accessible tactile maps from geographical data. Lastly, general-purpose vector graphics editors, though not designed exclusively for tactile output, can be adapted to produce files suitable for embossing or other tactile printing methods. These software categories collectively facilitate the transformation of visual designs into physical tactile outputs via braille embossers, swell paper machines, or 3D printers.[2]

1 https://www.perkins.org/resource/tactile-graphics-library/ https://www.tactileview.com/ https://bpb-us-e1.wpmucdn.net/wp.nyu.edu/dist/c/1540/files/2022/08/Design-Guidelines-for-Tactile-Maps.pdf https://touch-mapper.org/en/help https://aeldata.com/stem-accessibility/tactile-graphics/

2 https://touch-mapper.org/en/help https://www.duxburysystems.com/dbt_details.asp https://irie-at.com/product/tactileview-design-software/ https://bpb-us-e1.wpmucdn.net/wp.nyu.edu/dist/c/1540/files/2022/08/Workflow-For-In-House-Production-Of-Paper-Tactile-Maps.pdf https://getbraille.com/tactile-graphics/ https://www.problind.org/en/create/ https://www.duxburysystems.com/products.asp https://blindsvg.com/

12.3 Commercial Tactile Graphics Software

12.3.1 TactileView Design Software

Core Functionality and Features

TactileView is a robust and comprehensive design software specifically engineered for creating tactile graphics. It offers an intuitive editor with a wide array of drawing tools and image processing filters, allowing users to easily design and produce tactile pictures, diagrams, and maps.[3] A notable feature is its integrated math module, which can generate graphs directly from equations, and the powerful RouteTactile map maker, capable of producing tactile maps at various scales, from country-level overviews to detailed street layouts.[4]

The software prioritizes accessibility, ensuring full compatibility with mouse, keyboard, and screen readers, thereby providing a seamless experience for all users.[5] TactileView supports the import of a broad range of image file formats, including.txt,.svg,.jpg,.png,.bmp,.tiff, and.gif, and saves designs in its proprietary.bpx format.[6] An extensive online catalog provides access to thousands of ready-to-use designs, enhancing efficiency for creators.[7] While TactileView can be used offline, certain advanced functions, such as the map maker and access to the designs catalog, require an internet connection.[8] A significant advantage is its ability to integrate with Duxbury Braille Translator (DBT), allowing for the creation of documents that combine both tactile graphics and braille text.[9]

3 https://www.duxburysystems.com/dbt_details.asp https://blindsvg.com/

4 https://www.duxburysystems.com/dbt_details.asp https://blindsvg.com/ https://www.duxburysystems.com/dbt_details.asp https://www.duxburysystems.com/news.asp https://www.duxburysystems.com/dbt_details.asp

5 https://www.duxburysystems.com/dbt_details.asp https://blindsvg.com/ https://www.duxburysystems.com/dbt_details.asp https://www.duxburysystems.com/dbt_details.asp

6 https://www.duxburysystems.com/dbt_details.asp https://blindsvg.com/ https://www.duxburysystems.com/news.asp https://www.duxburysystems.com/dbt_details.asp https://www.duxburysystems.com/dbt_details.asp

7 https://www.duxburysystems.com/dbt_details.asp https://blindsvg.com/ https://www.duxburysystems.com/news.asp https://www.duxburysystems.com/dbt_details.asp

8 https://www.duxburysystems.com/dbt_details.asp https://blindsvg.com/ https://www.duxburysystems.com/news.asp https://www.duxburysystems.com/dbt_details.asp https://www.duxburysystems.com/dbt_details.asp

9 https://www.duxburysystems.com/dbt_details.asp

System Requirements (Windows, MacOS via Emulator)

TactileView is primarily a Windows-native application. It supports a broad spectrum of Microsoft Windows operating systems, including older versions such as XP, Vista, 7, 8, 8.1, and newer iterations like Windows 10 and 11.[10] For users operating on Mac OS X, a Windows emulator is explicitly required to run TactileView, which introduces an additional layer of software and potential performance considerations.[11]

The provided information does not specify explicit minimum or recommended CPU, RAM, or storage requirements for TactileView.[12] This suggests that the software is designed to operate efficiently on a wide range of standard, modern computer systems, and does not typically demand high-end hardware specifications beyond what is generally expected for the supported operating systems.

Embosser and Thermal Device Compatibility

TactileView demonstrates extensive compatibility with a wide array of braille embossers and thermal tactile graphics machines. It supports embossers from major manufacturers, including Index (V2, V3, V4, Basic-D V5, Everest-D V5), ViewPlus (all models, such as VP Columbia 2, VP Delta 2, VP Max, VP SpotDot, VP Premier, VP Elite), and Enabling Technologies (all models, including Romeo 60 and Juliet 120).[13] The software also supports printing on swell paper (microcapsule paper) and is compatible with thermal devices like PIAF (Pictures in a Flash) and Swell Form machines.[14] This broad compatibility ensures that users with various existing embossing hardware can leverage TactileView for their tactile graphic production needs.

[10] https://www.duxburysystems.com/dbt_details.asp https://blindsvg.com/ https://www.duxburysystems.com/news.asp https://www.duxburysystems.com/dbt_details.asp https://www.duxburysystems.com/dbt_details.asp

[11] https://www.duxburysystems.com/dbt_details.asp https://blindsvg.com/ https://www.duxburysystems.com/news.asp https://www.duxburysystems.com/dbt_details.asp https://www.duxburysystems.com/dbt_details.asp

[12] https://www.duxburysystems.com/dbt_details.asp https://blindsvg.com/ https://www.duxburysystems.com/news.asp https://www.duxburysystems.com/dbt_details.asp https://www.duxburysystems.com/dbt_details.asp

[13] Source: https://www.duxburysystems.com/dbt_details.asp https://blindsvg.com/ https://www.duxburysystems.com/dbt_details.asp https://www.duxburysystems.com/dbt_details.asp

[14] Source: https://www.duxburysystems.com/dbt_details.asp https://www.duxburysystems.com/dbt_details.asp https://www.duxburysystems.com/dbt_details.asp

12.3.2 ElPicsPrint

Core Functionality and Features

ElPicsPrint is a specialized software designed for the preparation and embossing of tactile images on braille embossers.[15] It offers a comprehensive suite of tools for object processing, including scaling, rotating, flipping, grouping, and alignment.[16] Users can modify contour properties such as stroke thickness, line type (solid, dotted), fill color, and tactile texture type, including dot height.[17] The software also facilitates the creation of complex shapes through operations like adding, subtracting, or intersecting contours, and allows for layering objects with adjustable overlay order (Z-index).[18] For full-color images, ElPicsPrint provides options to adjust upper and lower thresholds for image detection, which can significantly influence the embossed output.[19]

A key strength of ElPicsPrint is its robust text features. It enables the creation and editing of text fields, with automatic conversion to braille using the Liblouis library and selected translation tables.[20] Users can also input braille directly via six-key entry and utilize braille label recognition to differentiate braille text from the image.[21] For printing, ElPicsPrint supports various methods, including its own dot algorithm for braille embossing, direct printing to microcapsule paper, and utilizing standard operating system printer drivers.[22] It supports common paper sizes like A4, A3, Letter, Legal, and Ledger, and allows for margin adjustments and image rotation for portrait orientation.[23] The software can import.jpg,.png, and.bmp image files, and supports opening and saving Scalable Vector Graphics (SVG) files (contours only).[24] It also uses its own.elpe (editable SVG) and.elpp (ready-to-emboss dot information) file formats.[25]

System Requirements (Windows)

ElPicsPrint is designed to run on Windows operating systems. While the research material explicitly states its compatibility with various embossers and its ability to

15 Source: `https://irie-at.com/product/tactileview-design-software/`
16 Source: `https://irie-at.com/product/tactileview-design-software/`
17 Source: `https://irie-at.com/product/tactileview-design-software/`
18 Source: `https://irie-at.com/product/tactileview-design-software/`
19 Source: `https://irie-at.com/product/tactileview-design-software/`
20 Source: `https://irie-at.com/product/tactileview-design-software/`
21 Source: `https://irie-at.com/product/tactileview-design-software/`
22 Source: `https://irie-at.com/product/tactileview-design-software/`
23 Source: `https://irie-at.com/product/tactileview-design-software/`
24 Source: `https://irie-at.com/product/tactileview-design-software/`
25 Source: `https://www.duxburysystems.com/dbt_details.asp`

process SVG files, it **does not provide specific minimum or recommended CPU, RAM, or storage requirements** for the software itself.[26] This absence of detailed hardware specifications suggests that ElPicsPrint is likely optimized to operate effectively on standard Windows computers without demanding high-performance components. The focus appears to be on its compatibility with a wide range of output devices rather than stringent computational demands.

Embosser and Thermal Device Compatibility

ElPicsPrint offers broad compatibility with a range of braille embossers and thermal tactile graphics devices. It is specifically designed to work with embossers manufactured by Index Braille, ViewPlus, and Enabling Technologies.[27]

Supported Embosser Models:

- *Index Braille:* Everest-D, BrailleBox, Basic-D, and FanFold-D (version 4 or higher).[28]
- *ViewPlus:* VP Delta, VP Columbia, VP Roque, VP EmBraille, VP Max, VP SpotDot, VP Elite, VP Premier.[29]
- *Enabling Technologies:* Romeo and Juliet.[30]

In addition to embossers, ElPicsPrint supports devices with thermal technology for printing on microcapsule paper, including Swell Form and PIAF machines.[31] This extensive compatibility allows users to select from a wide range of hardware for producing tactile graphics.

12.3.3 Duxbury Braille Translator (DBT) & QuickTac

Core Functionality and Features (Braille Translation with Graphics Integration)

Duxbury Braille Translator (DBT) is an industry-leading software primarily known for its robust print-to-braille translation capabilities, supporting over 180 languages and various

[26] Source: `https://irie-at.com/product/tactileview-design-software/` `https://www.duxburysystems.com/dbt_details.asp`
[27] `https://irie-at.com/product/tactileview-design-software/`
[28] `https://irie-at.com/product/tactileview-design-software/` `https://www.duxburysystems.com/dbt_details.asp`
[29] `https://irie-at.com/product/tactileview-design-software/` `https://www.duxburysystems.com/dbt_details.asp`
[30] `https://irie-at.com/product/tactileview-design-software/` `https://www.duxburysystems.com/dbt_details.asp`
[31] Source: `https://irie-at.com/product/tactileview-design-software/`

braille codes, including UEB (Unified English Braille).[32] It excels at formatting braille pages, automating the conversion process, and allowing direct editing in both print and braille views.[33] DBT can import a wide range of modern file formats, including Microsoft Word documents (2003-365), Open Office, and Excel files.[34] It also supports mathematics and science text translation into braille.[35]

While DBT's core strength is braille translation, it possesses the crucial ability to include tactile graphics files for mixed text-and-graphic documents.[36] This integration is largely facilitated by **QuickTac**, a companion freeware program from Duxbury Systems specifically designed for creating embosser graphics.[37] QuickTac functions as a paint program that builds a grid of dots, which can then be directly embossed or saved into a file (specifically the.SIG format) for import into DBT.[38] This workflow addresses the challenge of tactile graphics, where a continuous line is often difficult to achieve with embossers.[39] The integration of QuickTac allows DBT users to produce documents containing both braille text and tactile illustrations, enhancing accessibility for complex materials.[40]

---

32 Source: https://www.duxburysystems.com/dbt_details.asp https://www.perkins.org/resource/how-create-3d-printable-maps-using-touch-mapper/ https://viewplus.com/downloads/cutsheets/TSS8_PS_EN_8.5x11_2023.pdf https://irie-at.com/product/brailletrac-120/ https://elitagroup.com/prod/elpicsprint/ https://viewplus.com/product/tiger-software-suite9/

33 Source: https://www.perkins.org/resource/how-create-3d-printable-maps-using-touch-mapper/

34 Source: https://www.perkins.org/resource/how-create-3d-printable-maps-using-touch-mapper/ https://irie-at.com/product/brailletrac-120/ https://elitagroup.com/prod/elpicsprint/ https://viewplus.com/product/tiger-software-suite9/

35 Source: https://www.perkins.org/resource/how-create-3d-printable-maps-using-touch-mapper/ https://elitagroup.com/prod/elpicsprint/ https://viewplus.com/product/tiger-software-suite9/

36 Source: https://touch-mapper.org/en/help https://www.perkins.org/resource/how-create-3d-printable-maps-using-touch-mapper/ https://elitagroup.com/prod/elpicsprint/ https://elitagroup.com/prod/elpicsprint/

37 Source: https://touch-mapper.org/en/help https://elitagroup.com/prod/elpicsprint/ https://elitagroup.com/prod/elpicsprint/ https://viewplus.com/downloads/cutsheets/TSS8_PS_EN_8.5x11_2023.pdf https://www.duxburysystems.com/dbt_details.asp https://softorage.com/software/inkscape/

38 Source: https://touch-mapper.org/en/help https://www.duxburysystems.com/dbt_details.asp

39 Source: https://viewplus.com/downloads/cutsheets/TSS8_PS_EN_8.5x11_2023.pdf

40 Source: https://touch-mapper.org/en/help https://www.duxburysystems.com/dbt_details.asp https://www.perkins.org/resource/how-create-3d-printable-maps-using-touch-mapper/ https://elitagroup.com/prod/elpicsprint/ https://elitagroup.com/prod/elpicsprint/

System Requirements (Windows, MacOS)

Duxbury Braille Translator (DBT):

- **Operating Systems:** DBT for Windows (DBT Win 14.1 SR1) requires Windows 8, 10, or 11.[41] Older versions also supported Windows 7.[42] For Mac users, DBT for Mac 14.1 recommends Mac OS X El Capitan (10.11) or higher, including Sierra (10.12) and High Sierra (10.13).[43]
- **Hardware:** The provided documentation for DBT does not specify explicit minimum or recommended CPU, RAM, or storage requirements.[44] This suggests that DBT is optimized to run efficiently on standard computer configurations that meet the specified operating system requirements.

QuickTac:

- **Operating Systems:** QuickTac for Windows runs on Windows 7 or above, with updates released in July 2020 to maintain compatibility.[45] For Mac users, QuickTac for Mac runs on Mac OS X Yosemite or above, also updated in July 2020.[46]
- **Hardware:** Similar to DBT, explicit CPU, RAM, or storage requirements for QuickTac are not detailed in the provided information.[47] QuickTac is described as a "paint program building a grid of dots" [**?**], implying it is not resource-intensive and can run on general system requirements for the specified operating systems.

41 https://www.perkins.org/resource/how-create-3d-printable-maps-using-touch-mapper/ https://irie-at.com/product/brailletrac-120/ https://elitagroup.com/prod/elpicsprint/

42 https://elitagroup.com/prod/elpicsprint/

43 https://irie-at.com/product/brailletrac-120/ https://elitagroup.com/prod/elpicsprint/ https://elitagroup.com/prod/elpicsprint/

44 https://www.perkins.org/resource/how-create-3d-printable-maps-using-touch-mapper/ https://viewplus.com/downloads/cutsheets/TSS8_PS_EN_8.5x11_2023.pdf https://irie-at.com/product/brailletrac-120/ https://elitagroup.com/prod/elpicsprint/ https://viewplus.com/product/tiger-software-suite9/ https://www.duxburysystems.com/dbt_details.asp

45 https://www.duxburysystems.com/products.asp

46 https://www.duxburysystems.com/products.asp

47 https://elitagroup.com/prod/elpicsprint/ https://elitagroup.com/prod/elpicsprint/ https://www.duxburysystems.com/products.asp https://elitagroup.com/manuals/elpicsprint/

Embosser Compatibility

Duxbury Braille Translator (DBT): DBT is designed to support "all commercial embossers," ranging from very old to quite recent models.[48] This broad compatibility is a significant advantage, allowing users to integrate DBT into diverse existing embossing setups. Recent updates have improved support for specific models, including ViewPlus Columbia, ViewPlus Delta (supporting booklet printing on 11x17 paper), Braillo (including Series 2 models like 300, 450, 600, and variable line spacing), Irie embossers (correcting front/back page alignment on BrailleTrac 120), TactPlus EasyTactix, ViewPlus SpotDot, APH PageBlaster, and APH PixBlaster.[49] DBT also supports Z-fold format on Index FanFold embossers.[50]

QuickTac: QuickTac produces tactile graphics files that can be imported into DBT.[51] When setting up an embosser in QuickTac, only models capable of producing graphics are displayed.[52] QuickTac-generated graphics (in.SIG format) can be produced on ViewPlus embossers when embedded in a DBT document.[53] This indicates that QuickTac's compatibility is primarily through its integration with DBT, leveraging DBT's extensive embosser support.

12.3.4 Tiger Software Suite (TSS)

Core Functionality and Features (ViewPlus Embosser Ecosystem)

The Tiger Software Suite (TSS) is a comprehensive software package developed by ViewPlus, designed to maximize the functionality of ViewPlus embossers.[54] It provides

48 https://www.perkins.org/resource/how-create-3d-printable-maps-using-touch-mapper/ https://irie-at.com/product/brailletrac-120/ https://elitagroup.com/prod/elpicsprint/ https://viewplus.com/product/tiger-software-suite9/ https://elitagroup.com/prod/elpicsprint/

49 https://softorage.com/software/inkscape/

50 https://softorage.com/software/inkscape/

51 https://touch-mapper.org/en/help https://elitagroup.com/prod/elpicsprint/ https://elitagroup.com/prod/elpicsprint/ https://viewplus.com/downloads/cutsheets/TSS8_PS_EN_8.5x11_2023.pdf https://www.duxburysystems.com/dbt_details.asp https://softorage.com/software/inkscape/

52 https://www.duxburysystems.com/dbt_details.asp

53 https://softorage.com/software/inkscape/

54 Source: https://emeraldcoastvisionaids.com/shop/products/tactileview-design-software/ https://elitagroup.com/manuals/elpicsprint/ https://www.duxburysystems.com/products.asp https://www.duxburysystems.org/documentation/NimPro/quick.htm

essential tools for braille translation and tactile graphics creation, making it a complete solution for braille production needs.[55]

TSS includes several key components:

- **VP Formatter:** This add-in integrates directly with Microsoft Word and Excel, allowing users to translate text to braille and convert images to tactile graphics within familiar Windows applications.[56] It supports interline printing, displaying print text alongside braille, which is beneficial for proofreading and for users new to braille.[57] The VP Formatter offers expert-level output with easy-to-use controls, enabling single-click embossing and customizable settings.[58]
- **Tiger Designer:** This is a standalone tactile graphics software that allows users to create or edit tactile graphics, leveraging ViewPlus embossers' capability for 8 different dot heights to produce high-resolution, world-class tactile graphics.[59] It can quickly convert existing images or generate unique tactile graphics using intuitive tools.[60] Tiger Designer also supports opening or importing PDFs, adjusting size, snap, and rotation with braille text recognition.[61] It offers a pattern editor with default patterns and the ability to assign tactile patterns to specific colors, applying color mapping automatically when printing to compatible ViewPlus embossers.[62]
- **VP Translator:** This tool can convert text from various Windows applications (e.g., PowerPoint, text files, websites) into braille based on user-preferred settings and send the document to a ViewPlus embosser.[63]

TSS supports customizable UEB Grade 2 contraction tables, updates to Liblouis, and

55 Source: https://emeraldcoastvisionaids.com/shop/products/tactileview-design-software/ https://www.duxburysystems.com/products.asp

56 Source: https://emeraldcoastvisionaids.com/shop/products/tactileview-design-software/ https://elitagroup.com/manuals/elpicsprint/ https://www.duxburysystems.org/documentation/NimPro/quick.htm

57 Source: https://emeraldcoastvisionaids.com/shop/products/tactileview-design-software/

58 Source: https://emeraldcoastvisionaids.com/shop/products/tactileview-design-software/ https://www.duxburysystems.org/documentation/NimPro/quick.htm

59 Source: https://emeraldcoastvisionaids.com/shop/products/tactileview-design-software/ https://elitagroup.com/manuals/elpicsprint/ https://www.duxburysystems.com/products.asp https://www.duxburysystems.org/documentation/NimPro/quick.htm

60 Source: https://emeraldcoastvisionaids.com/shop/products/tactileview-design-software/ https://www.duxburysystems.org/documentation/NimPro/quick.htm

61 Source: https://elitagroup.com/manuals/elpicsprint/

62 Source: https://elitagroup.com/manuals/elpicsprint/

63 Source: https://emeraldcoastvisionaids.com/shop/products/tactileview-design-software/ https://www.duxburysystems.org/documentation/NimPro/quick.htm

includes Braille36 fonts for better OS interoperability across Windows, Mac, and Linux.[64] It also allows experienced graphic designers to use familiar applications like Adobe Illustrator and CorelDraw and print directly to ViewPlus embossers.[65] The software enables ink printing to any mainstream color printer.[66]

System Requirements (Windows)

The provided information for Tiger Software Suite primarily focuses on its features and embosser compatibility rather than detailed system requirements. While it is stated that TSS runs on Windows, specific minimum or recommended CPU, RAM, or storage requirements are not explicitly provided.[67] However, the compatibility section for ViewPlus embossers, which are powered by TSS, mentions Windows 7, 8/8.1, and 10 as compatible operating systems.[68] This suggests that TSS is designed to function effectively on standard Windows systems that meet general modern computing needs.

Embosser Compatibility

Tiger Software Suite is specifically developed to power and fully utilize **all ViewPlus embossers**, from portable models like EmBraille to high-volume/high-speed units such as the Elite.[69] This tight integration ensures optimal performance and access to advanced features like 8-dot height tactile graphics.[70]

While primarily designed for ViewPlus embossers, TSS is also compatible with Duxbury and other mainstream braille software, indicating a degree of interoperability within the

64 Source: https://elitagroup.com/manuals/elpicsprint/
65 Source: https://elitagroup.com/manuals/elpicsprint/ https://www.duxburysystems.com/products.asp https://touch-mapper.org/
66 Source: https://elitagroup.com/manuals/elpicsprint/
67 Source: https://emeraldcoastvisionaids.com/shop/products/tactileview-design-software/ https://elitagroup.com/manuals/elpicsprint/ https://www.duxburysystems.com/products.asp https://www.duxburysystems.org/documentation/NimPro/quick.htm
68 Source: https://www.duxburysystems.com/products.asp
69 Source: https://emeraldcoastvisionaids.com/shop/products/tactileview-design-software/ https://elitagroup.com/manuals/elpicsprint/ https://www.duxburysystems.com/products.asp https://www.duxburysystems.org/documentation/NimPro/quick.htm
70 Source: https://emeraldcoastvisionaids.com/shop/products/tactileview-design-software/ https://www.duxburysystems.com/products.asp

broader braille production ecosystem.[71] The software leverages standardized Windows printer drivers, allowing for basic printing to ViewPlus embossers even without specialized software, but TSS enhances this with multi-language braille translation and document formatting.[72] The ability to import and work with Scalable Vector Graphics (SVG) files within Tiger Designer further extends its utility, as SVG is a widely recognized format for vector imagery.[73] This allows users of other vector graphics applications to prepare designs for ViewPlus embossers.

12.4 Open-Source Tactile Graphics Software

12.4.1 Inkscape

Core Functionality and Features (Vector Graphics for Tactile Output)

Inkscape is a professional-quality, free, and open-source vector graphics software that runs natively on Windows, Mac OS X, and GNU/Linux.[74] It is widely used by designers and hobbyists for creating a diverse range of graphics, including illustrations, icons, logos, diagrams, maps, and web graphics.[75] Inkscape's native format is SVG (Scalable Vector Graphics), an open standard from the W3C.[76]

While not exclusively designed for tactile graphics, Inkscape is highly adaptable for this purpose due to its vector-based nature. Tactile graphics can be created quickly and easily using its tools.[77] Key functions relevant to tactile output include flexible drawing tools, shape tools, interactive transformations (move, scale, rotate, skew), layer organization, grouping, and precise control over fill and stroke settings.[78] It supports multi-line text and text placement along paths, which is crucial for adding braille labels.[79] The software's ability to handle SVG files is particularly advantageous, as SVG is a common format for generating embossed graphics, raised-line prints with Swell-Form

71 Source: https://emeraldcoastvisionaids.com/shop/products/tactileview-design-software/ https://www.duxburysystems.com/products.asp https://touch-mapper.org/ https://steemit.com/utopianio/@jingis07/reviewing-inkscape-professional-vector-graphics-editor-1554816723337
72 Source: https://elitagroup.com/manuals/elpicsprint/
73 Source: https://elitagroup.com/manuals/elpicsprint/ https://irie-at.com/product/brailletrac-120/
74 https://getbraille.com/tactile-graphics/ https://blindhelp.net/software/DBT
75 https://blindhelp.net/software/DBT
76 https://blindhelp.net/software/DBT
77 Source: https://getbraille.com/tactile-graphics/
78 Source: https://www.duxburysystems.com/faq2.asp?faq=13
79 Source: https://www.duxburysystems.com/faq2.asp?faq=13

printing, and even extrusion maps for 3D printers.[80] Users can create custom illustrations, schematics, blueprints, charts, graphs, and maps for tactile production.[81]

Specific considerations for tactile graphics in Inkscape include limiting drawings to a few colors (e.g., black, grey, oldLace) to produce strong lines and good textures with multi-dot height embossers, and using a minimum stroke width of 2 units for embossed graphics (1 unit for Swell-Form/3D printing).[82] The software allows for the creation of templates, which can then be uploaded to databases like "Share" for community access.[83]

System Requirements (Windows, MacOS, Linux)

Inkscape is known for being relatively light on system resources and is compatible across major operating systems.[84]

- Operating Systems: Inkscape runs on Windows, Mac OS X, and GNU/Linux.[85] It is also available on FreeBSD and web-based platforms.[86]
- Minimum Hardware Requirements:
  - CPU: 1 GHz processor.[87]
  - RAM: 256 MB.[88]
  - Storage: The executable file size for installation is approximately 80 MB, and it occupies about 375 MB after installation, indicating a small footprint.[89]
- Recommended Hardware for Complex Graphics:
  - For smoother performance, especially when working with large or high-resolution images, a 2.40 GHz processor with 8 GB of RAM is commonly used.[90]
  - For handling multiple tasks without slowing down, particularly with complex graphics work, 16 GB of RAM is recommended.[91]

80 Source: `https://www.problind.org/en/create/`
81 Source: `https://www.problind.org/en/create/`
82 Source: `https://www.problind.org/en/create/`
83 Source: `https://getbraille.com/tactile-graphics/`
84 `https://blindhelp.net/software/DBT` `https://blindhelp.net/software/DBT`
85 `https://blindhelp.net/software/DBT`
86 `https://blindhelp.net/software/DBT`
87 `https://blindhelp.net/software/DBT`
88 `https://blindhelp.net/software/DBT`
89 `https://blindhelp.net/software/DBT`
90 `https://blindhelp.net/software/DBT`
91 `https://blindhelp.net/software/DBT`

- Any graphics card capable of displaying the work is generally sufficient.[92]

- Limitations: While Inkscape is lightweight, it may experience performance issues, including hangs, lags, or crashes, when dealing with very large or complicated projects.[93] Compatibility issues can arise when transferring files between Inkscape and other graphics software, potentially leading to a loss of certain features.[94] It also lacks built-in cloud-based services for file synchronization and collaboration.[95]

Embosser Workflow and Compatibility Considerations

Inkscape does not offer direct, built-in embosser support or specific drivers. Instead, its strength lies in its ability to produce SVG files, which serve as an intermediate format for tactile output.[96] The workflow for creating tactile graphics with Inkscape and sending them to an embosser or swell form machine typically involves several steps:

1. Design in Inkscape: Create the tactile graphic design, ensuring adherence to tactile design principles (e.g., minimum object distance, limited textures, appropriate line thickness).[97] Braille labels can be added directly, often using specific fonts like Courier New 27 pt.[98]
2. Export/Save as SVG: Save the design as an SVG file.[99] This vector format is crucial as it allows for scaling without pixelation, maintaining quality for tactile output.[100]
3. Preparation for Embossing:
    - For braille embossers, the SVG file can often be printed through standard operating system tools, where the printer driver generates the tactile image.[101] Some embossers, particularly ViewPlus Tiger embossers, are designed to work with SVG files and can interpret color brightness to create different dot

92 https://blindhelp.net/software/DBT
93 https://blindhelp.net/software/DBT
94 https://blindhelp.net/software/DBT
95 https://blindhelp.net/software/DBT
96 https://www.problind.org/en/create/ https://www.duxburysystems.org/documentation/NimPro/quick.htm
97 https://www.problind.org/en/create/ https://www.duxburysystems.com/dbt_details.asp
98 https://getbraille.com/tactile-graphics/
99 https://www.problind.org/en/create/
100 https://blindhelp.net/software/DBT
101 https://irie-at.com/product/tactileview-design-software/

heights.[102]

- For swell paper machines (e.g., PIAF, Swell Form), the SVG design is typically printed onto swell paper using a laser printer, then passed through the thermal machine to raise the inked areas.[103]
- The workflow may involve duplicating layers for color and black-and-white versions for combined tactile and visual prints.[104]

4. External Translation/Processing: In some cases, the SVG file might be imported into specialized tactile graphics software (like ElPicsPrint or Tiger Designer) for final processing, braille translation (if not done in Inkscape), and embossing.[105] This approach leverages Inkscape's design capabilities while relying on dedicated software for optimal embosser control.
5. Browser-based Printing: For certain embossers, printing SVGs directly from web browsers like Google Chrome or Firefox can be effective.[106]

The flexibility of SVG as an open standard makes Inkscape a valuable tool in tactile graphics production, enabling a workflow that can be adapted to various embossing technologies, even without direct software-level embosser integration.[107]

12.4.2 Touch Mapper

Core Functionality and Features (Specialized Tactile Map Generation)

Touch Mapper is a specialized web-based tool designed for the easy creation of custom outdoor tactile maps for individuals who are blind or partially sighted.[108] Its primary

[102] https://www.problind.org/en/create/ https://www.duxburysystems.com/products.asp https://www.duxburysystems.com/products.asp https://irie-at.com/product/brailletrac-120/
[103] https://www.duxburysystems.com/products.asp https://www.duxburysystems.org/documentation/NimPro/quick.htm https://www.duxburysystems.org/name=Products;action-uri=/OldRoot/products.html
[104] https://www.duxburysystems.org/documentation/NimPro/quick.htm
[105] Source: https://www.duxburysystems.com/dbt_details.asp https://elitagroup.com/manuals/elpicsprint/
[106] Source: https://www.problind.org/en/create/
[107] https://www.problind.org/en/create/
[108] https://aeldata.com/stem-accessibility/tactile-graphics/ https://bpb-us-e1.wpmucdn.net/wp.nyu.edu/dist/c/1540/files/2022/08/Workflow-For-In-House-Production-Of-Paper-Tactile-Maps.pdf https://ability2access.com/products-2/tiger-software-suite-tss/

function is to help users orient themselves and plan routes by providing tactile representations of geographical areas.[109]

The process is straightforward: users enter an address, click "Search," then "Create tactile map," and finally choose to print or order the map.[110] Touch Mapper utilizes OpenStreetMap data as its source, which, while generally excellent, may occasionally have missing features.[111] The maps generated are optimized for clarity and the practical needs of visually impaired individuals, rather than being true-to-life representations.[112] They can include roads (pedestrian roads are raised more), buildings, railways, and water bodies (with wavy surfaces, narrow streams as lines).[113] A raised dot on one corner typically marks the Northeast corner for orientation.[114]

A key limitation is that Touch Mapper-generated maps do not include any text or labels directly on the map, necessitating a separate written or brailled description to accompany the map for full utility.[115] The platform supports creating maps in multiple parts for larger areas, which can be laid side-by-side.[116] Commercial use of maps created with Touch Mapper is permitted, provided the source (www.touch-mapper.org) is clearly credited.[117]

System Requirements (Web-Based)

As a web-based application, Touch Mapper's system requirements are primarily dependent on the user's web browser and internet connectivity.

- Operating Systems: Compatible with any operating system capable of running a modern web browser (Windows, MacOS, Linux, mobile OS).[118]

[109] https://aeldata.com/stem-accessibility/tactile-graphics/ https://bpb-us-e1.wpmucdn.net/wp.nyu.edu/dist/c/1540/files/2022/08/Workflow-For-In-House-Production-Of-Paper-Tactile-Maps.pdf
[110] Source: https://bpb-us-e1.wpmucdn.net/wp.nyu.edu/dist/c/1540/files/2022/08/Workflow-For-In-House-Production-Of-Paper-Tactile-Maps.pdf
[111] Source: https://aeldata.com/stem-accessibility/tactile-graphics/
[112] Source: https://aeldata.com/stem-accessibility/tactile-graphics/
[113] Source: https://aeldata.com/stem-accessibility/tactile-graphics/
[114] Source: https://aeldata.com/stem-accessibility/tactile-graphics/ https://ability2access.com/products-2/tiger-software-suite-tss/
[115] Source: https://aeldata.com/stem-accessibility/tactile-graphics/ https://ability2access.com/products-2/tiger-software-suite-tss/
[116] Source: https://aeldata.com/stem-accessibility/tactile-graphics/
[117] Source: https://aeldata.com/stem-accessibility/tactile-graphics/
[118] Source: https://aeldata.com/stem-accessibility/tactile-graphics/ https://bpb-us-e1.wpmucdn.net/wp.nyu.edu/dist/c/1540/files/2022/08/Workflow-For-In-House-Production-Of-Paper-Tactile-Maps.pdf https://ability2access.com/products-2/tiger-software-suite-tss/

- Hardware: Minimal hardware requirements for the computer itself, as the processing is done server-side. A stable internet connection is necessary to access the service and generate maps.[119]
- Local Printing: If printing maps locally, the computer must meet the requirements of the specific 3D printer, braille embosser, or swell paper printer being used.

Embosser, Swell Paper, and 3D Printer Compatibility

Touch Mapper supports various output methods for tactile maps:

- 3D Printers: Users can download an STL file of the map at no charge and print it themselves using almost any 3D printer, including affordable hobbyist devices.[120] Recommendations for 3D printing include layer thickness of 0.25 mm or 0.3 mm, a base thickness of 0.6 mm (two layers), two top layers, and one horizontal shell.[121] Printing time for a 17 cm map is around 3-4 hours.[122]
- Embossers: Tactile embossers are supported for printing the maps.[123] The color brightness in the digital design can influence the resolution and dot height on a braille embosser.[124]
- Swell Paper Printers (Thermal Devices): Swell paper printers are also supported.[125] This method involves printing the map design on swell paper using a laser printer and then passing it through a Swell Form Machine to raise the inked areas.[126] This method is noted for being easy to learn and reproduce, offering a greater level of graphical detail than braille embossers, though the paper cost is higher and braille text may be less clear.[127]

---

119 Source: https://aeldata.com/stem-accessibility/tactile-graphics/ https://bpb-us-e1.wpmucdn.net/wp.nyu.edu/dist/c/1540/files/2022/08/Workflow-For-In-House-Production-Of-Paper-Tactile-Maps.pdf https://ability2access.com/products-2/tiger-software-suite-tss/

120 Source: https://aeldata.com/stem-accessibility/tactile-graphics/ https://bpb-us-e1.wpmucdn.net/wp.nyu.edu/dist/c/1540/files/2022/08/Workflow-For-In-House-Production-Of-Paper-Tactile-Maps.pdf https://ability2access.com/products-2/tiger-software-suite-tss/

121 Source: https://aeldata.com/stem-accessibility/tactile-graphics/

122 Source: https://aeldata.com/stem-accessibility/tactile-graphics/

123 Source: https://bpb-us-e1.wpmucdn.net/wp.nyu.edu/dist/c/1540/files/2022/08/Workflow-For-In-House-Production-Of-Paper-Tactile-Maps.pdf

124 Source: https://www.duxburysystems.com/products.asp

125 Source: https://bpb-us-e1.wpmucdn.net/wp.nyu.edu/dist/c/1540/files/2022/08/Workflow-For-In-House-Production-Of-Paper-Tactile-Maps.pdf

126 Source: https://www.duxburysystems.com/products.asp

127 Source: https://www.duxburysystems.com/products.asp

Touch Mapper's flexibility in output formats makes it a versatile tool for creating tactile maps, catering to different production capabilities and user preferences.

12.4.3 BrailleBlaster

Core Functionality and Features (Braille Production with Graphics Potential)

BrailleBlaster is an open-source braille transcription and production software primarily focused on creating braille documents. It is designed to assist in producing braille for various materials, including textbooks. While its core strength lies in braille translation and formatting, it has the potential for integrating or handling graphics within braille documents. The software aims to be a comprehensive solution for braille production, supporting multiple languages and offering features for complex document layouts.

System Requirements (Windows, MacOS, Linux)

BrailleBlaster is designed to run on common desktop operating systems, with specific hardware recommendations for optimal performance.

- Operating Systems:
  - Windows: Windows 10 or newer.[128] Older versions supported Windows 7 or higher.[129]
  - Mac OS: Mac OS X or newer.[130]
  - Linux: Ubuntu Linux 20.04 or later. For universal zip archive distribution, Java 15 or higher is required.[131] Older versions supported Linux with Java 8 installed.[132]
- Hardware Requirements:

[128] Source: https://sterlingadaptives.com/products/viewplus-premier-braille-embosser-tiger-software-suite-included

[129] Source: https://sterlingadaptives.com/products/viewplus-premier-braille-embosser-tiger-software-suite-included

[130] Source: https://sterlingadaptives.com/products/viewplus-premier-braille-embosser-tiger-software-suite-included

[131] Source: https://sterlingadaptives.com/products/viewplus-premier-braille-embosser-tiger-software-suite-included

[132] Source: https://sterlingadaptives.com/products/viewplus-premier-braille-embosser-tiger-software-suite-included

- Processor: 64-bit computer with a 64-bit operating system installed.[133] No specific CPU speed or core count is mentioned, implying general modern processor compatibility.
- RAM: Minimum of 4 GB RAM, with 6 GB recommended for better performance.[134]
- Storage: Not explicitly stated, but typically modest for document processing software.
- Graphics: Works best with a high-resolution monitor, though it is not a strict requirement.[135]

Embosser Compatibility

The provided information indicates that BrailleBlaster is a tool for braille production, which inherently implies compatibility with braille embossers. However, the available snippets **do not explicitly detail a list of specific embosser brands or models** that BrailleBlaster directly supports for tactile graphics output. Its primary function as a braille editor suggests it would likely utilize standard printer drivers for embossing, similar to how other braille translation software interacts with hardware. The focus of BrailleBlaster is on translating and formatting text into braille, with the potential for graphics integration being a secondary or indirect capability.

12.5 Comparative Analysis: Choosing the Right Solution

The selection of appropriate software for generating tactile graphics involves a careful evaluation of operating system compatibility, hardware demands, embosser integration, feature sets, and the fundamental choice between commercial and open-source models.

[133] Source: https://sterlingadaptives.com/products/viewplus-premier-braille-embosser-tiger-software-suite-included

[134] Source: https://sterlingadaptives.com/products/viewplus-premier-braille-embosser-tiger-software-suite-included

[135] Source: https://sterlingadaptives.com/products/viewplus-premier-braille-embosser-tiger-software-suite-included

12.5.1 Operating System Support Across Platforms

The landscape of tactile graphics software exhibits a clear bias towards Windows, which hosts the majority of commercial, feature-rich applications. TactileView and ElPicsPrint are Windows-native, requiring a Windows emulator for MacOS users.[136] This presents a barrier for MacOS users who prefer not to run virtual environments. Duxbury Braille Translator (DBT) offers native versions for both Windows (Windows 8, 10, 11) and MacOS (OS X El Capitan or higher) [**?**, **?**, **?**], making it a more versatile choice for cross-platform environments. Tiger Software Suite (TSS) is primarily a Windows solution, deeply integrated with Microsoft Office applications.[137]

For Linux users, the options are more limited in the commercial space. Open-source solutions like Inkscape provide robust vector graphics editing capabilities natively on Linux, Windows, and MacOS.[138] BrailleBlaster also supports all three major operating systems (Windows 10+, Mac OS X+, Ubuntu Linux 20.04+).[139] Web-based tools like Touch Mapper offer the highest degree of OS independence, as they can be accessed from any device with a modern web browser and internet connection.[140] This broadens accessibility for users across different computing environments, including those running Linux or mobile operating systems.

12.5.2 Hardware Demands: CPU, RAM, Storage, Graphics

Detailed hardware specifications are not consistently provided across all software, particularly for commercial products like TactileView and ElPicsPrint, which typically state only operating system compatibility. This often indicates that these applications are not exceptionally resource-intensive and can run effectively on standard modern computers.

- **TactileView & ElPicsPrint:** Specific CPU, RAM, or storage requirements are not

[136] Source: https://www.duxburysystems.com/dbt_details.asp https://blindsvg.com/ https://www.duxburysystems.com/news.asp https://www.duxburysystems.com/dbt_details.asp https://www.duxburysystems.com/dbt_details.asp

[137] Source: https://emeraldcoastvisionaids.com/shop/products/tactileview-design-software/ https://elitagroup.com/manuals/elpicsprint/

[138] Source: https://blindhelp.net/software/DBT

[139] Source: https://sterlingadaptives.com/products/viewplus-premier-braille-embosser-tiger-software-suite-included

[140] Source: https://aeldata.com/stem-accessibility/tactile-graphics/ https://bpb-us-e1.wpmucdn.net/wp.nyu.edu/dist/c/1540/files/2022/08/Workflow-For-In-House-Production-Of-Paper-Tactile-Maps.pdf https://ability2access.com/products-2/tiger-software-suite-tss/

listed for these commercial applications.[141] Their performance is likely tied to the underlying operating system's general requirements.

- **Duxbury Braille Translator (DBT) & QuickTac:** Similar to the above, explicit hardware requirements are largely absent.[142] QuickTac, being a simple paint program, is inherently light.[143]
- **Inkscape:** As an open-source vector graphics editor, Inkscape has modest minimum requirements (1 GHz CPU, 256 MB RAM, 375 MB storage).[144] However, for handling large or high-resolution images and complex projects, 8 GB of RAM is commonly used, and 16 GB is recommended for smoother performance and multitasking.[145] It is generally considered light on system resources, with CPU usage remaining low unless working on demanding files.[146]
- **BrailleBlaster:** This open-source braille production software requires a 64-bit computer with a 64-bit operating system, a minimum of 4 GB RAM (6 GB recommended), and works best with a high-resolution monitor.[147]
- **Touch Mapper:** Being web-based, its hardware demands on the client machine are minimal, relying primarily on a stable internet connection and a modern web browser.[148] The hardware requirements for actual printing (3D printer, embosser) are separate.

In summary, while most dedicated tactile graphics software does not impose stringent hardware demands, general-purpose vector editors like Inkscape can benefit significantly

---

141 Source: https://www.duxburysystems.com/dbt_details.asp https://irie-at.com/product/tactileview-design-software/ https://blindsvg.com/ https://www.duxburysystems.com/news.asp https://www.duxburysystems.com/dbt_details.asp https://www.duxburysystems.com/dbt_details.asp https://www.duxburysystems.com/dbt_details.asp

142 Source: https://www.perkins.org/resource/how-create-3d-printable-maps-using-touch-mapper.pdf https://viewplus.com/downloads/cutsheets/TSS8_PS_EN_8.5x11_2023.pdf https://irie-at.com/product/brailletrac-120/ https://elitagroup.com/prod/elpicsprint/ https://viewplus.com/product/tiger-software-suite9/ https://elitagroup.com/prod/elpicsprint/ https://www.duxburysystems.com/products.asp https://elitagroup.com/manuals/elpicsprint/

143 Source: https://www.duxburysystems.com/dbt_details.asp

144 Source: https://blindhelp.net/software/DBT

145 Source: https://blindhelp.net/software/DBT https://blindhelp.net/software/DBT

146 Source: https://blindhelp.net/software/DBT

147 Source: https://sterlingadaptives.com/products/viewplus-premier-braille-embosser-tiger-software-suite-included

148 Source: https://aeldata.com/stem-accessibility/tactile-graphics/ https://bpb-us-e1.wpmucdn.net/wp.nyu.edu/dist/c/1540/files/2022/08/Workflow-For-In-House-Production-Of-Paper-Tactile-Maps.pdf https://ability2access.com/products-2/tiger-software-suite-tss/