Understanding and Reducing Inaccuracy in Electronically Generated Braille

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**Understanding and Reducing Inaccuracies in Electronically Generated Braille**

# Introduction

Which refreshable braille devices work with Unified English Braille? Can refreshable braille be used in online testing? Do we even need braille transcribers anymore now that we can download books onto an iPad and connect a braille display? These common questions are quite understandable given the profusion of technology and information that educators, braille users, and purchasing decision-makers encounter. A meaningful answer to any of these questions requires some understanding of the actuality and the potential for accuracy in automatic braille translation.

Refreshable braille is a foundational tool for literacy for blind people in our digital age. Unified English Braille, with its clearly defined rules and symbol structures, provides, on its own or in combination with other specialized braille codes, a means to render both accurate braille representation of any non-image-based content that originated in print, and accurate "back translation" to print of material electronically typed in braille. However, the accuracy of electronically-generated braille often does not meet its potential due to a number of factors, most of which are correctable. One of the largest obstacles to addressing the problem of inaccurate electronic braille is lack of awareness (on the part of teachers who work with braille-reading students, those responsible for purchasing decisions, braille readers themselves, and even those who create and purvey the technology), of the complex origins and scope of the problem or of its impact on the development of literacy and on the usefulness of braille as a means of communication and collaboration.

This paper will explore the details of the problems and effects of inaccurate braille generated by electronic means and offer suggestions for ways that all stakeholders can be involved in bringing about improvements.

# Background: Braille Hardware and Screen Reader Basics

A glance at the list of refreshable braille displays that can be used with devices from Apple or Google gives the sense of the wide range of currently available refreshable braille displays. They vary by the number of cells they contain (anywhere from twelve to eighty), type of keyboard for input, how the refreshable braille is moved forward or back, size and weight, and other features. However, modern braille displays can be grouped into two basic types:

**Braille displays with no internal memory or independent functionality.** These devices can only be used when connected, by a cable or wirelessly, to a desktop computer, tablet, smartphone, or other mainstream device running screen reading software. All braille translation, back translation, and other display function is driven by the screen reader and its interaction with the material being read or written. Whether or not this device can display in UEB is entirely defined by the screen reader to which it is connected. This type of braille display may or may not include a keyboard for writing on or controlling the computer or mobile device. Examples of these displays include Brailliant and BrailleConnect (Humanware), Focus (Freedom Scientific), BraillePen (Harpo), and Easy Braille (HandyTech).

**Braille displays which can be connected to other devices, as above, or which can operate as "stand-alone notetakers".** These have their own internal operating systems and braille translation, and they have either a QWERTY or a six-key keyboard. Some can function almost like full-fledged computers, with their own internet connectivity and email clients, web browsers, word processors, calculators, chat programs and so on. Some are more basic, with no internet connectivity and perhaps a word processor, a calculator, and a PDF viewer. Most current models of these devices, with a few exceptions, have incorporated UEB into their internal braille translation, although some may present the issues with inaccuracy that will be discussed later. The user interface of these devices is usually quite different from that of mainstream devices and can provide a more seamless experience tailored to the needs of a braille user. However, the functionality of their proprietary applications is often more limited than that of their mainstream counterparts. For example, some of the internal web browsers are challenged when trying to render particularly complicated or feature-rich web pages. Examples of braille displays that can operate either independently or with an external device include VarioUltra (BAUM), BrailleNote (Humanware), Braille Sense (HIMS), Braille Edge (HIMS).

# The Path From Electronic Print To Electronic Braille

Although Unified English Braille has largely removed the conflicts within the braille code that could cause ambiguity and inaccuracy, additional factors and variables on the path of text moving from print into braille can cause variations in the quality of the final braille output. An understanding of the many ways that braille material can be created and the variety of methods for accessing it is critical to ensuring that the braille reader will be able to read the same information as a print reader would gain from the same material in print form. The quality of the braille is influenced by the features of the original print material, the software's adherence to the rules of Unified English Braille, whether knowledgeable human intervention is involved where applicable, and the capacity of the hardware used to read the material.

## Types of Material That Can Be Read in Refreshable Braille

### Electronic Braille Prepared By A Transcriber

In this case, all of the action of creating the braille takes place *before* it is loaded into a refreshable braille device. The screen reader is not involved in the translation. The transcriber brailles the document on a computer, with or without the assistance of braille translation software. In ideal cases, the document is formatted with hierarchical heading levels, properly indented paragraphs and listed items, print page numbers, tables, picture descriptions, etc. The final versions of such files are often known as Braille Ready Files (BRF). Such documents can be embossed onto paper, sent by email attachment, downloaded from the web, or distributed by flash drive or other physical media.

To read a BRF, the user opens the file either using a stand-alone notetaker or a mainstream device in an application specially designed to handle BRF files (such as the BARD Mobile app from the National Library Service for the Blind and Physically Handicapped). The user simply opens the file and reads. The user cannot contract or uncontract or make other global changes to the presentation without creating a completely separate file.

### Electronic Braille Prepared by a Remote Software Process

Here again, all of the translation action happens before the document reaches the braille reader's device. How much of the formatting is retained from the print depends upon the features of the original document and the capacity of the remote braille software to deal with formatting. Picture descriptions and other image-based content is not included unless it was added in the print version before the translation to braille. These documents are also delivered as BRF and can be embossed onto paper, sent by email attachment, downloaded from the web, or distributed by flash drive or other physical media.

### Self-Contained Print-Based Documents

These include documents produced by a word processor, PDFs, DAISY files, eBook formats, plain text files, etc. They can be sent by email attachment, downloaded from the web, or distributed by flash drive or other physical media. The action of braille translation happens via the user's technology in two possible ways as discussed below. The quality of the braille version is determined by features of the original document and by the adherence of the screen reader to braille rules.

For self-contained print-based documents, the user can do one of two things to read the document in braille:

1. Open and read the existing document in a word processer, book reader, PDF viewer, or similar. The screen reader or notetaker translates the material into braille "on-the-fly"—that is, the entire document is not translated at once, but a few words are translated at a time as they are displayed. The person reading the braille can control some aspects of the presentation by changing settings.

2. If a stand-alone notetaker is being used, and if the original document's file type is supported by the notetaker, the user can first translate the entire document to braille—creating a completely separate file—then open that file for reading. Although there is less control over the presentation as well as possible loss of some navigation features after the translation occurs, sometimes, more of the other aspects of the original document can be retained in braille through this method. The user can also more easily do searches or make braille notes within this braille translated version of the document.

### Print-Based Web Pages, Applications, or Communications

Emails, text messages, social media, applications used on a mobile device, and web sites fit into this category of interactive material. This material is generally only accessed in braille through real-time on-the-fly translation done by the screen reader. Some stand-alone notetakers include their own proprietary email clients, web browsers, and other applications for communication and collaboration, also using real-time translation. These proprietary clients may have some features tailored for the braille user but may also be more limited in their functionality than their mainstream counterparts. The user has some control over the braille presentation by changing settings on the screen reader; for example, the user can switch between uncontracted and contracted braille presentation. The quality of the braille output depends on how the original content was created and how well the screen reader handles the braille translation.

## Reading Mathematics in Refreshable Braille

Electronically generated mathematics comes in many flavors. Mathematics in a BRF created by a knowledgeable transcriber can be read in refreshable braille if the reading system supports BRFs. Under the right conditions, linear mathematics can also be read with real-time on-the-fly translation. Unfortunately, math is often created in a manner that screen readers cannot handle—sometimes all in graphic images, sometimes in math editors not compatible with screen readers. When the math is properly encoded using MathML, the VoiceOver and NVDA screen readers have particularly well-developed ability to show the math in the Nemeth code or in UEB. An online equation editor recently developed by Pearson, for use in online testing, can translate MathML to Nemeth. Math created in LaTex or in MathType can also be used to make the material available in braille. Stand-alone notetakers generally cannot reliably import print-based self-contained documents with math content. Full-fledged, dedicated braille translation programs like Duxbury or Braille2000 have much more advanced capability to handle print-based documents with properly encoded math. For further information on this complex subject, see [Further Information on Math in Refreshable Braille](#_Further_Information_on) at the end of this paper.

## Factors Outside of Braille Errors That Affect the Reading Experience

**Support for file type of original material.** Stand-alone notetakers vary in which types of files they can handle. PDFs, spreadsheets, RTF, and others have all presented challenges at times. In some cases the devices can open earlier versions of the file types, but not the ones created by the newest release of the programs. In the realm of mainstream applications and devices connected to braille displays, very few applications can open Braille Ready Format files without a great deal of user intervention.

**Loss of Features Present in Original Material.** Notetakers and mainstream apps also vary by how much of the information they can glean and use from the original. Sometimes notetakers can extract just the text but do not show the page numbers, font attributes, and the like and do not preserve the navigation by chapters or sections that was available in the original print-based file. When using braille displays with external devices, some of the navigation is more likely to remain, but other features may not be available. For example, in the Kindle app on iOS, it is not possible to use the hyperlinks to reference notes using braille. Searching, when using a BRF on a notetaker, is fairly straightforward, whereas using the search field and browsing the results on a mainstream book reading app is doable but can be cumbersome. In every case, any meaning conveyed only by pictures, diagrams, or color is lost unless specific steps were taken by the creator of the original to make the information available in other formats.

# The Path From Electronic Braille to Electronic Print

Braille is, of course, not just for reading. The ability to use braille for writing—to keep notes, communicate with others, prepare assignments, work mathematics, write great literature, support developing reading skills, and so on—is one of braille's greatest assets and is critical to maintain in the digital age.

## Types of Writing in Refreshable Braille

Writing using braille on an electronic device also can be grouped into three basic types. Which method is used is determined both by what technology the user has available and by what kind of material is being written.

### Type QWERTY, Read Braille

The user types into a computer with a standard keyboard, a print keyboard connected to a mobile device, or a stand-alone refreshable braille notetaker that has a QWERTY keyboard instead of six braille keys. Although neither the document being created nor the typing input is in braille, braille translation and display is necessary for the user to read and check what he or she is writing. The translation from print to braille occurs instantaneously during typing; only what is shown on the braille display is translated—not the entire document. The user can set the screen reader to display in contracted or uncontracted braille. The material is already in print, and therefore, after it has been typed and edited, it can be printed, shared, saved, and the like without any further action.

### Type in Braille for Immediate Back Translation to Print

A braille display with a six-key keyboard can be used to type in mainstream applications on a computer or mobile device. Back translation to print occurs almost instantaneously during typing—either after a short interval when typing stops, or after a space or other designated keystroke is pressed. The back translation process is driven by the screen reader, and not all screen readers can accept contracted braille input for back translation. The following table shows the braille input capacity of the latest versions of five popular screen readers for desktop and mobile platforms:

| Screen Reader | Braille Input |
| --- | --- |
| JAWS (PC) | Contracted |
| Window-Eyes (PC) | Computer braille only |
| NVDA (PC) | Computer braille only |
| VoiceOver (MacOS and iOS) | Contracted |
| TalkBack with BrailleBack (Android) | Computer braille only |

It should be kept in mind that, in cases where in print there is no direct way to type a font attribute like italics or superscript, the braille indicators also cannot be typed to switch these font attributes on and off when typing in a mainstream application. Assuming that the application being used can support more than plain text, the text must be selected, and then the attribute applied using application menus.

The material that has been typed must also be displayed so that the user can read and edit it. The screen reader can be set to display contracted or uncontracted braille, regardless of whether the typing was done in contracted or uncontracted. The separateness of these two processes can sometimes make it easier for the user to spot braille typing mistakes.

The material is already in print, and therefore, after it has been typed and edited, it can be printed, shared, saved, and the like without any further action.

### Type in Braille, Back Translate Later (If At All)

When using a six-key device in stand-alone notetaker mode, braille can be typed without applying translation of any kind. As typing occurs, the display shows exactly the dot configurations that have been typed. This is very similar to brailling onto paper. In this "native" braille environment, if the document is only for personal use, the person creating it can make up symbols or shorthand if desired. Editing is fairly straightforward. If a print version of the document is needed, after the typing and editing is complete, it can then be back translated and exported to a print based format for sharing with others. On notetakers with email or other communication capability, email messages and other communications can be typed and edited in this way, with no translation to print occurring until the message is actually sent. Braille users learn to check their work very carefully before sending or exporting, since even one innocuous-seeming out-of-place braille dot can cause a very noticeable error in print, like a totally different word from what was intended.

When creating documents in this way, the braille indicators for italics and the like can sometimes be used in UEB with their effects retained if they are supported in the chosen print-based format. More reliably for back translation, a specific keystroke is used to turn on the italics before typing the words to be italicized and then using the keystroke again to toggle off the italics. Braille typeform indicators are not displayed. Most notetakers are capable of applying a fair amount of formatting so that the resulting print document looks as intended, but it is difficult to check the print document without reading it on a computer.

At least one braille display offers a hybrid between immediate back translation and this method. A single paragraph of text can be typed in braille on the six-key braille display and edited in braille before being sent to an external device, where it is then back translated.

## Writing Mathematics in Refreshable Braille

Using refreshable braille to write and work math for personal purposes, when no back translation is needed, is fairly straightforward except for the limitations inherent in being able to view only one line of braille at a time.

Back translation of math braille to print can be accomplished on some stand-alone notetakers, where the entire document is typed in braille and then exported. The print export results from some notetakers show the math constructs in words, such as (open superscript) or (end frac), while others can show the exact print symbols and constructs. If the math is brailled using the Nemeth code, a keystroke is used to switch into and out of Nemeth mode when writing math along with text in words. Some notetakers do not allow for switching into Nemeth unless the translation is set to "English US"—that is, the English braille used before the adoption of UEB; this can and should be remedied so that users who wish to do so can use Nemeth within UEB contexts.

The simplest mathematics, written in UEB, can be back translated in real time in screen readers that support back translation. However, even simple fractions, superscripts and subscripts, or anything else beyond very basic symbols are not yet supported in screen readers. Code switching in real-time back translation does not appear to be supported in any scenario at this time, but the existing [defined braille code switch indicators](#Provisional) are one available tool that should help make this possible. The "hybrid" back translation process discussed in the previous section also holds some promise for helping to overcome the limitations. A recently developed [online equation editor from Pearson,](#Pearson) for use in online testing, supports back translation of Nemeth code into print MathML content. Even when built-in screen reader support for math does improve, real-time back translation of any but the most basic mathematics will need to be done in an application that can support print math constructs.

# Basic Categories of Braille Errors

1a. **Errors that can cause annoyance but do not introduce ambiguity.** These errors can affect the ease of reading and obscure the pronunciation, and, especially if frequent within the text, can make for a challenging reading experience. However, they do not hinder determination of the spelling of the word, and they will not back translate incorrectly. Examples include contractions used in cases where they should not be used *within grade 2 mode.* Contractions used when not in grade 2 mode are in Category 3 below.

1B. **Errors that can cause annoyance and use more space on a page or braille display but do not introduce ambiguity.** These errors can affect the ease of reading and obscure the pronunciation, and, especially if frequent within a text, can make for a challenging reading experience. They also cause fewer words to be able to show at one time on a refreshable braille display, which already has an extremely limited display area. However, they do not hinder determination of the spelling of the word, and they will not back translate incorrectly. Examples include contractions not used where they should be used and capital word indicators where passage indicators should be used.

2. **Known ambiguity introduced.** The braille reader can tell that something is there, but there is no way to tell what it is exactly. This includes symbols that display as full cells or gibberish.

3. **Errors that change the meaning.** The braille material reads comprehensibly but reads and back translates completely differently from the intent of the original print because of a print symbol translating to a braille symbol with a different meaning, or because of a breach of modes. Examples include a grade 1 symbol indicator or numeric indicator omitted where it should be used.

4A. **Content omissions arising from the braille software's inability to render features of the print.** The information does render in braille if the content is imported and then translated in its entirety, but generally it is left out with on-the-fly translation. Examples include font attributes such as bold, strike-through, superscript, italics.

4B. **Content omissions arising from characteristics of the original file that cannot be interpreted at all by the screen reader.** Such features include images and/or color used to convey essential content, diagrams, or even routine text that is put in as graphics. Electronic versions of math or science books and tests, product manuals, and graphic novels often include such content omissions if there is no human intervention.

# Samples of electronic braille generated by five screen readers

The following examples show some common errors encountered when reading in contracted Unified English Braille with real-time translation from a Microsoft Word document. This is a sample of the kinds of errors directly encountered by this author over many years of daily use of screen-reader-generated contracted braille. It is not intended as a comparison of the accuracy among the screen readers, but rather as a representative sampling of commonly-occurring errors and in what situations they happen. Notes to the errors explain the problem and, where applicable, explain how it can be corrected. All of the errors still exist as of March 1, 2016.

Some of the screen readers are known to utilize Liblouis, a third-party, open-source translation system. Judging from the fact that no two screen readers yield exactly the same errors, each of the screen readers using Liblouis appears to be using a different version. Note that Bookshare.org, a widely used online accessible library providing books in BRF created on-demand with automatic translation, uses LibLouis as well, and so the Bookshare books also currently include these types of errors. Also note that not all of the screen readers use Liblouis for braille translation, but all presently generate at least some errors.

The following screen reader versions were used:

• JAWS — version 17.0.1377, running on a PC with Microsoft Word 2010

• Window-Eyes — version 9.3.1, running on a PC with Microsoft Word 2010

• VoiceOver — included with iOS 9.2.1, running on an iPhone 6S+ with Microsoft Word

• BrailleBack — version 0.95.1-prod, running with Lollipop 5.1 on a Nexus 7″ 2012 with Tipa Reader

• NVDA — version 2016.1, running on a PC with Microsoft Word 2010

Note: Most of the screen readers cannot yet accept contracted braille input for back translation. The "Back Translation" column in these examples shows both a print representation of what the braille reader sees on the display and how the characters in the "Braille" column, if typed using six keys, *would* back translate if the feature were available and working accurately in the screen reader.

### Example 1: A Phone number

|  | **Braille** | **Back Translation** | **Notes** |
| --- | --- | --- | --- |
| Correct | #fad-#bed-#cage | 614-254-3175 |  |
| JAWS | #fad-bed-cage | 614-bed-cage | [[7](#Note7)] |
| Window-Eyes | #fad-#bed-#cage | 614-254-3175 |  |
| VoiceOver | #fad-#bed-#cage | 614-254-3175 |  |
| BrailleBack | #fad-bed-cage | 614-bed-cage | [[7](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note7)] |
| NVDA | #fad-#bed-#cage | 614-254-3175 |  |

### Example 2: Common Word #1

|  | **Braille** | **Back Translation** | **Notes** |
| --- | --- | --- | --- |
| Correct | boyfr | boyfriend |  |
| JAWS | boyfr | boyfriend |  |
| Window-Eyes | boyfr | boyfriend |  |
| VoiceOver | boyfr | boyfriend |  |
| BrailleBack | boyfri5d | boyfriend | [[3](#Note3)] |
| NVDA | boyfr | boyfriend |  |

## Example 3: Time of Day

|  | **Braille** | **Back Translation** | **Notes** |
| --- | --- | --- | --- |
| Correct | #aa3#cj | 11:30 |  |
| JAWS | #aa3cj | 11:cj | [[7](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note7)] |
| Window-Eyes | #aa3#cj | 11:30 |  |
| VoiceOver | #aa3#cj | 11:30 |  |
| BrailleBack | #aa3cj | 11:cj | [[7](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note7)] |
| NVDA | #aa3#cj | 11:30 |  |

## Example 4: A Citation

|  | **Braille** | **Back Translation** | **Notes** |
| --- | --- | --- | --- |
| Correct | pages #abc-#abf | pages 123-126 |  |
| JAWS | pages #abc-abf | pages 123-abf | [[7](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note7)] |
| Window-Eyes | pages #abc-#abf | pages 123-126 |  |
| VoiceOver | pages #abc-#abf | pages 123-126 |  |
| BrailleBack | pages #abc-abf | pages 123-abf | [[7](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note7)] |
| NVDA | pages #abc-#abf | pages 123-126 |  |

## Example 5: A Decade

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Braille** | **Back Translation** | **Notes** |
| Correct | #aigjs | 1970s |  |
| JAWS | #aigj;s | 1970s | [[2](#Note2)] |
| Window-Eyes | #aigjs | 1970s |  |
| VoiceOver | #aigjs | 1970s |  |
| BrailleBack | #aigj;s | 1970s | [[2](file:///C:\Users\jdunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note2)] |
| NVDA | #aigjs | 1970s |  |

## Example 6: A Web Address Containing a Number

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Braille** | **Back Translation** | **Notes** |
| Correct | #d;chances4com | 4chances.com |  |
| JAWS | #d;\*.es4com | 4\*εs.com | [[8](#Note8)] |
| Window-Eyes | #d;chances4com | 4chances.com |  |
| VoiceOver | #d;chances4com | 4chances.com |  |
| BrailleBac | #d;\*.es4com | 4\*εs.com | [[8](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note8)] |
| NVDA | 4chances.com | dischancescom | [[9](#Note9)] |

## Example 7: Section Subdivision Within A Text

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Braille** | **Back Translation** | **Notes** |
| Correct | #ae4a;g4 | 15.1g. |  |
| JAWS | #ae4ag4 | 15.17 | [[7](#Note7)] |
| Window-Eyes | #ae4a;g4 | 15.1g. |  |
| VoiceOver | #ae4a;g4 | 15.1g. |  |
| BrailleBack | #ae4ag4 | 15.17. | [[7](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note7)] |
| NVDA | #ae4a;g4 | 15.1g. | [[7](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note7)] |

## Example 8: A Company Name

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Braille** | **Back Translation** | **Notes** |
| Correct | ,,at@&,t | AT&T |  |
| JAWS | ,,at@&;,t | AT&T | [[2](file:///C:\Users\jdunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note2)] |
| Window-Eyes | ,,at@&,t | AT&T |  |
| VoiceOver | ,,at@&,t | AT&T |  |
| BrailleBack | ,,at@&;,t | AT&T | [[2](file:///C:\Users\jdunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note2)] |
| NVDA | ,,at@&;,t | AT&T | [[2](file:///C:\Users\jdunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note2)] |

## Example 9: In Care Of

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Braille** | **Back Translation** | **Notes** |
| Correct | c\_/o | c/o |  |
| JAWS | ;c\_/o | c/o | [[2](file:///C:\Users\jdunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note2)] |
| Window-Eyes | c\_/o | c/o |  |
| VoiceOver | c\_/o | c/o |  |
| BrailleBack | ;c\_/o | c/o | [[2](file:///C:\Users\jdunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note2)] |
| NVDA | ;c\_/;o | c/o | [[2](file:///C:\Users\jdunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note2)] |

## Example 10: A Person's Initials

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Braille** | **Back Translation** | **Notes** |
| Correct | ;,e4 ;,m4 ,=/] | E. M. Forster |  |
| JAWS | ,e4 ,m4 ,=/] | Every. More. Forster | [[7](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note7)] |
| Window-Eyes | ;,e4 ;,m4 ,=/] | E. M. Forster |  |
| VoiceOver | ;,e4 ;,m4 ,=/] | E. M. Forster |  |
| BrailleBack | ,e4 ,m4 ,=/] | Every. More. Forster | [[7](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note7)] |
| NVDA | ;,e4 ;,m4 ,=/] | E. M. Forster |  |

## Example 11: Common Word #2

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Braille** | **Back Translation** | **Notes** |
| Correct | rev]e | revere |  |
| JAWS | r"ee | revere | [[1](#Note1)] |
| Window-Eyes | rev]e | revere |  |
| VoiceOver | rev]e | revere |  |
| BrailleBack | r"ee | revere | [[1](#Note1)] |
| NVDA | r"ee | revere | [[1](#Note1)] |

## Example 12: Common Word #3

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Braille** | **Back Translation** | **Notes** |
| Correct | pr$ict | predict |  |
| JAWS | predict | predict | [[3](#Note3)] |
| Window-Eyes | pr$ict | predict |  |
| VoiceOver | pr$ict | predict |  |
| BrailleBack | predict | predict | [[3](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note3)] |
| NVDA | predict | predict | [[3](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note3)] |

## Example 13: Another Company Name

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Braille** | **Back Translation** | **Notes** |
| Correct | ,d\ble"d | Doubleday |  |
| JAWS | ,d\bl$ay | Doubleday | [[1](#Note1)] |
| Window-Eyes | ,d\bl$ay | Doubleday | [[1](file:///C:\Users\jdunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note1)] |
| VoiceOver | ,d\bl$ay | Doubleday | [[1](file:///C:\Users\jdunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note1)] |
| BrailleBack | ,d\bl$ay | Doubleday | [[1](file:///C:\Users\jdunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note1)] |
| NVDA | ,d\bl$ay | Doubleday | [[1](file:///C:\Users\jdunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note1)] |

## Example 14: A City Name

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Braille** | **Back Translation** | **Notes** |
| Correct | ,2!sda | Bethesda |  |
| JAWS | ,be!sda | Bethesda | [[3](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note3)] |
| Window-Eyes | ,be!sda | Bethesda | [[3](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note3)] |
| VoiceOver | ,be!sda | Bethesda | [[3](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note3)] |
| BrailleBack | ,be!sda | Bethesda | [[3](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note3)] |
| NVDA | ,be!sda | Bethesda | [[3](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note3)] |

## Example 15: Fractions

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Braille** | **Back Translation** | **Notes** |
| Correct | #a/b #a/c | ½ ⅓ |  |
| JAWS | #a/b = |  | [[6](#Note6), [11](#Note11)] |
| Window-Eyes | #a/b -- |  | [[11](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note11)] |
| VoiceOver | #a/b #a/c |  | [[6](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note6), [11](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note11)] |
| BrailleBack | ?1/2# '\x2153' |  | [[11](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note11), [16](#Note16)] |
| NVDA | '\x00bd' '\x2153' |  | [[6](#Note6), [15](#Note15)] |

## Example 16: Subscript

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Braille** | **Back Translation** | **Notes** |
| Correct | ,h;5#b,o | H2O |  |
| JAWS | ;,h#b,o | H2o | [[2](#Note2), [10](#Note10)] |
| Window-Eyes | ,h#b,o | H2o | [[10](#Note10)] |
| VoiceOver | ,h#b,o | H2o | [[10](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note10)] |
| BrailleBack | ;,h#b,o | H2o | [[2](#Note2), [10](#Note10)] |
| NVDA | ;,h#b,o | H2o | [[2](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note2), [10](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note10)] |

## Example 17: The Temperature

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Braille** | **Back Translation** | **Notes** |
| Correct | #ge^j,f | 75ºF | [[12](#Note12)] |
| JAWS | #gedg;,f | #7547F | [[2](#Note2), [6](#Note6), [12](#Note12)] |
| Window-Eyes | #ge"9,f | 75\*F | [[6](#Note6), [12](#Note12)] |
| VoiceOver | #ge@$u+ba,f |  | [[6](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note6), [12](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note12)] |
| BrailleBack | #ge'\x00ba',f |  | [[2](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note2), [6](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note6), [12](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note12), [15](file:///C:\Users\jdunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note15)] |
| NVDA | #ge'\x00ba';,f |  | [[2](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note2), [6](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note6), [12](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note12), [15](#Note15)] |

## Example 18: Emphasis

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Braille** | **Back Translation** | **Notes** |
| Correct | .1,%e did x4 | *She* did it. |  |
| JAWS | ,%e did x4 | She did it. | [[10](#Note10)] |
| Window-Eyes | ,%e did x4 | She did it. | [[10](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note10)] |
| VoiceOver | ,%e did x4 | She did it. | [[10](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note10)] |
| BrailleBack | ,%e did x4 | She did it. | [[10](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note10)] |
| NVDA | ,%e did x4 | She did it. | [[10](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note10)] |

## Example 19: An Amendment

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Braille** | **Back Translation** | **Notes** |
| Correct | \_1,limit$ funds @#1d @#1n a3rue | Limited credits ~~do not~~ accrue |  |
| JAWS | ,limit$ funds d n a3rue | Limited funds do not accrue | [[10](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note10)] |
| Window-Eyes | ,limit$ funds d n a3rue | Limited funds do not accrue | [[10](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note10)] |
| VoiceOver | ,limit$ funds d n a3rue | Limited funds do not accrue | [[10](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note10)] |
| BrailleBack | ,limit$ funds d n a3rue | Limited funds do not accrue | [[10](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note10)] |
| NVDA | ,limit$ funds d n a3rue | Limited funds do not accrue | [[10](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note10)] |

## Example 20: Emoji

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Braille** | **Back Translation** | **Notes** |
| Correct | @.<w9k+ face@.> | 😉 |  |
| JAWS | == | forfor | [[6](#Note6)] |
| Window-Eyes | ---- | ---- | [[6](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note6)] |
| VoiceOver | \_4 | • | [[6](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note6)] |
| BrailleBack | '\x00f0''\x0178' |  | [[6](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note6)] |
| NVDA | '\xd800''\xdf04' |  | [[6](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note6), [15](#Note15)] |

## Example 21: Fully Capitalized

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Braille** | **Back Translation** | **Notes** |
| Correct | ,,,&y's be/ "d "e,' | ANDY'S BEST DAY EVER |  |
| JAWS | ,,&y',s ,,be/ ,,"d ,,"e | ANDY'S BEST DAY EVER | [[4](#Note4)] |
| Window-Eyes | ,,&y',s ,,be/ ,,"d ,,"e | ANDY'S BEST DAY EVER | [[4](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note4)] |
| VoiceOver | ,,&y',s ,,be/ ,,"d ,,"e | ANDY'S BEST DAY EVER | [[4](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note4)] |
| BrailleBack | ,,&y',s ,,be/ ,,"d ,,"e | ANDY'S BEST DAY EVER | [[4](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note4)] |
| NVDA | ,,&y';,s ,,be/ ,,"d ,,"e | ANDY'S BEST DAY EVER | [[2](#Note2), [4](#Note4)] |

## Example 22: Apostrophe or Single Quotation Mark?

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Braille** | **Back Translation** | **Notes** |
| Correct | cdn't | couldn’t |  |
| JAWS | cdn't | couldn’t |  |
| Window-Eyes | c\ldn,0t | couldn’t | [[5](#Note5)] |
| VoiceOver | c\ldn't | couldn’t | [[5](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note5)] |
| BrailleBack | cdn't | couldn’t |  |
| NVDA | cdn';t | couldn’t | [[2](file:///C:\Users\jdunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note2)] |

## Example 23: Partially Capitalized

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Braille** | **Back Translation** | **Notes** |
| Correct | ,u,copy | UCopy |  |
| JAWS | ,,ucopy | UCOPY | [[7](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note7)] |
| Window-Eyes | ,u,copy | UCopy |  |
| VoiceOver | ,,uc,'opy | UCopy | [[14](#Note14)] |
| BrailleBack | ;,u,copy | UCopy | [[2](#Note2), [14](#Note14)] |
| NVDA | ,,uc,'opy | UCopy | [[14](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note14)] |

## Example 24: Quadratic Formula

|  |  |  |
| --- | --- | --- |
|  | **Braille** | **Notes** |
| Correct—Nemeth Code | X .k ?-b+->b^2"-4ac]/2a# |  |
| Correct—UEB | ;;x"7("-b\_6%b9#b"-#d;ac+./#b;a) |  |
| JAWS | =="7==\_6"%==#b"-#d====#b== | [[13](#Note13)] |
| Window-Eyes | --"7--\_6"%--#b"-#d--#b-- | [[13](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note13)] |
| VoiceOver | (blank] | [[13](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note13)] |
| BrailleBack | (string of Unicode values) | [[13](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note13)] |
| NVDA | (string of Unicode values) | [[13](file:///C:\Users\JDunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper.docx#Note13)]] |

## Notes to Examples

[1] A contraction is used where it should not be used ([category 1a](#category1a) above). This incorrect contraction usage is specific to this word and its derivatives and may or may not occur in other words affected by the same braille rule. This error can be resolved by correcting software rules about the use of contractions. The solution also may lie in either adding the word to the software's word list or removing it from a word list that had been adapted from one based on pre-UEB rules.

[2] A grade 1 symbol indicator appears where it is unnecessary ([category 1B](#Category1B) above). The error is not limited to this specific word and will occur in all similar situations. This error can be resolved by correcting software rules about initiation and termination of modes and about the definition of "standing alone" (UEB 2.6, 5.7, 6.5.1-6.5.2).

[3] A contraction is not used where it should be used ([category 1b](#Category1B) above) This contraction omission is specific to this word but may occur in situations affected by the same braille rule. This error can be resolved by correcting software rules about the use of contractions (UEB 10). The solution also may lie in either adding the word to a wordlist or removing it from a wordlist that was adapted from a list based on pre-UEB rules.

[4] Capitalized passage indicators are not used; a capital word indicator precedes each word in the passage ([category 1B](#Category1B) above). At this time, the use of passage indicators of any kind is apparently only available when an entire file is translated, not with real-time translation. However, older versions of JAWS included a translation package that attempted, with moderate success, to use capitals passage indicators.

[5] The apostrophe displays as a two-cell single closing quotation mark. This could be considered either [category 1B](#Category1B) or [Category 3](#Category3). When the braille closing quotation mark is used, wordsigns and shortforms are prohibited for use in a word where they would have been allowed if an apostrophe were present (UEB 2.6.4). Many common words ending in "apostrophe s" or "apostrophe t" are affected by this issue. It occurs in Window-Eyes whenever Unicode 2019 is used for apostrophe. In VoiceOver, the problem has been partially fixed so that Unicode 2019 now displays the braille apostrophe, but rules are still applied as if the symbol were a closing quotation mark so that wordsigns and shortforms are not used in these words.

[6] The symbol is displayed in braille characters that clearly have no relation to the intended symbol ([category 2](#Category2) above). The symbol in some cases can be spoken aloud meaningfully by the screen reader, but no useful information is provided in braille. This error can be resolved by ensuring that all symbols with braille equivalents are mapped correctly. In cases such as emoji where no braille equivalent exists for the print symbol, a short description enclosed in transcriber's note indicators could convey the meaning to the reader in the same way that it is conveyed by speech. Such descriptions would not back translate to the print emoji symbols, and would need to be selected from a list for insertion into the document, in the same way that the symbols are selected by the print user.

[7] A grade 1 indicator or a numeric indicator is not used where it should be used, or incorrect capital indicators cause the capitalization to be inaccurate ([category 3](#Category3) above). The error occurs not just in this instance but in all similar situations. This error can be resolved by correcting software rules about termination and initiation of modes.

[8] Contractions are used without correctly terminating numeric mode or grade 1 mode ([category 3](#Category3) above). The error occurs in this screen reader in every instance where contractions directly follow numbers, except with the "st" and "th" contraction, which have apparently been programmed specially in recognition of ordinal numbers. This error can be resolved by correcting rules about grade 1 remaining in effect when numeric mode is terminated (UEB 5.6.1-5.6.2)

[9] Certain character strings, such as those containing ".com" or "@", are being partially or entirely translated into Computer Braille Code (CBC), which was formerly used for all electronic addresses and filenames but is not used within UEB ([category 3](#Category3) above). Some screen readers, even when they can accept contracted braille input, are also still erroneously requiring the use of CBC for braille input in edit fields and displaying the results in CBC. The unambiguous symbol structure of UEB allows accuracy of braille input and makes CBC obsolete for this particular purpose.

[10] Italics, subscripts, underlining, and the like are present and convey meaning in print but are not shown in braille ([category 4A](#Category4a) above). Some (but not all) screen readers do offer a method for showing font attributes in braille, involving the use of dots 7 and 8 below each affected character as well as a status cell at one end of the display to indicate which attribute is being shown. The information must be actively sought, and settings must be set correctly to access it. For font attributes such as strikethrough which have no defined braille equivalents, the transcriber-defined typeform indicators could be used to signal the presence of a change in the typeform but would not indicate the exact nature of the change. A solution should be devised.

[11] Some fraction symbols display correctly, but when they are typed for back translation, they translate as the two digits without the fraction or something else incorrect, unless the file is typed and exported from a stand-alone notetaker with robust UEB support. Note that there is no way to type these symbols directly in print, either—even when using an app in which they are supported, the fraction symbols must be selected from a list.

[12] Several types of "degrees" symbols can be used in print. One of them, (Unicode 00b0) actually does yield the correct braille symbol in most screen readers. The symbol used in this example, however, is Unicode 00ba. This symbol was used because JAWS provides a very convenient way to bring up a list of common symbols for inserting into a document, and Unicode 00ba is used for degrees in that list rather than 00b0). Either 00ba should be mapped to the braille "degrees" symbol, or the JAWS symbols list should be changed to use 00b0 instead.

[13] The screen reader's ability to display mathematics is highly dependent upon the way the math was created. The equation in this example was created with Word's built-in equation editor. It may be possible to render it correctly from a screen reader if MathType were installed and if the screen reader supported MathType, which only some do. When the Word document with this equation was imported into the Duxbury Braille Translator, the equation translated correctly into braille, with the import template set either to translate the math to UEB or to Nemeth code in a UEB context.

[14] A capitals terminator is placed so that it breaks up a natural subunit within a word, and this use of capital indicators takes up extra space as well ([category 1B](#Category1B) above). This error can be resolved by correcting software rules affecting choice of capitalization (UEB 8.8.2).

[15] This screen reader displays in braille the Unicode values for these symbols and uses computer braille to do so.

[16] This screen reader displays some of the fraction symbols in the Nemeth Code, which would only be appropriate if the fractions were in a mathematical context. This error can be resolved by mapping the print fraction symbols to UEB constructions (UEB 11.3).

# Suggestions for Bringing About Improvement in Accuracy of Electronic Braille

**Specific Improvements To Frameworks.** Support for contracted braille input in screen readers is needed, so that braille can be written directly when using electronic devices.

The display of Computer Braille Code for electronic addresses within Unified English Braille should be discontinued, as should the requirement to use CBC in edit fields on web sites and elsewhere. The *ability* to display in computer code should be retained, however, as it can still be useful for reading computer programs in braille, and for reading material [displayed in simulated braille](file:///C:\Users\jdunnam\Dropbox\Braille%20Display%20related%20writing\iceb%20paper%20mar%206.docx#Tutorial) that would be unintelligible on a refreshable braille display without the ability to switch to computer braille.

Better support for display and back translation of typeform and other font attributes should be sought.

Further development is needed in the arena of electronic braille mathematics. Support for math real-time back translation is needed. More screen readers should be able to render properly encoded math in braille. Notetakers should support the use of Nemeth within UEB contexts.

Additionally, screen reader companies and purveyors of BRF versions of books who use on-demand automatic braille translation should require and support timely improvements in the translation software that they use.

**Coordinated Error Reporting.** Particularly for when multiple screen readers make use of the same braille translation system, a coordinated mechanism is needed for users to report individual errors or suggest improvements, so that the fixes can happen more quickly. Such a mechanism should allow for reporting without the user being required to subscribe to an email list. A vetting method would be needed to ensure that reported errors are really errors.

**Credential.** Certification exists for braille transcribers, to ensure that braille readers have access to the quality material that their print reading counterparts do. Some type of braille testing and credential for screen readers for different aspects of their braille creation could be developed so that purchasing/usage decisions could be made with better information.

**Developer "How-To".** A manual or "overview" could be created for translation software developers, concisely but thoroughly explaining the important fundamentals of Unified English Braille like modes, rules, word lists, standing alone, and code switching. Section 2 and the appendices of the [*Rules of Unified English Braille Second Edition 2013*](http://www.iceb.org/ueb.html) are excellent places to start, if developers are aware of them as a critical resource. Developers of new programs or those just beginning to utilize existing ones for their own software must understand these basics before putting work into their programs. Such a guide could also include documents for testing.

**Education For Teachers And Braille Users.** A comprehensive guide is needed for educators and braille readers, explaining some of the significant nuances and complexities of working with refreshable braille (such as the benefits and drawbacks of on-the-fly versus native braille environments, etc.).

# Further Reading

## Screen Reader User Guides and Update Announcements

Latest NVDA Release Enhancements (NV Access) [http://www.nvaccess.org/files/nvda/releases/2016.1/nvda\_2016.1\_changes.html](http://www.nvaccess.org/files/nvda/releases/2016.1/nvda_2016.1_changes.html%20)

Latest JAWS Release Enhancements (Freedom Scientific) [https://www.freedomscientific.com/Downloads/JAWS/JAWSWhatsNew#Enhancements](https://www.freedomscientific.com/Downloads/JAWS/JAWSWhatsNew%23Enhancements)

Window-Eyes 9.1 Manual (Ai Squared) <http://getwindoweyes.com/Window-Eyes/Manual/HTML/advanced.html>

JAWS Braille Display Input Commands (Freedom Scientific) <http://www.freedomscientific.com/Content/html/jawshq/JAWS-braille-keystrokes.html>

NVDA 2016.1 User Guide (NV Access) <http://www.nvaccess.org/files/nvda/documentation/userGuide.html>

Install and Enable BrailleBack--Android Accessibility Help (Google, Inc.) <https://support.google.com/accessibility/android/answer/3535226?hl=en>

VoiceOver User Guide, Chapter 10, Using Braille Displays (Apple, Inc.) <https://www.apple.com/voiceover/info/guide/_1129.html>

## Further Information on Mathematics in Refreshable Braille

How Can Publishers Create Accessible Math Textbooks (DO-IT, University of Washington) <http://www.washington.edu/doit/how-can-publishers-create-accessible-math-textbooks?384=>

MathPlayer User Manual (Design Science) <http://www.dessci.com/en/products/mathplayer/manual.htm>

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