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Design of Interfaces for People with Blindness

Designing the Complete Learning Environment for Braille Users Studying Mathematics

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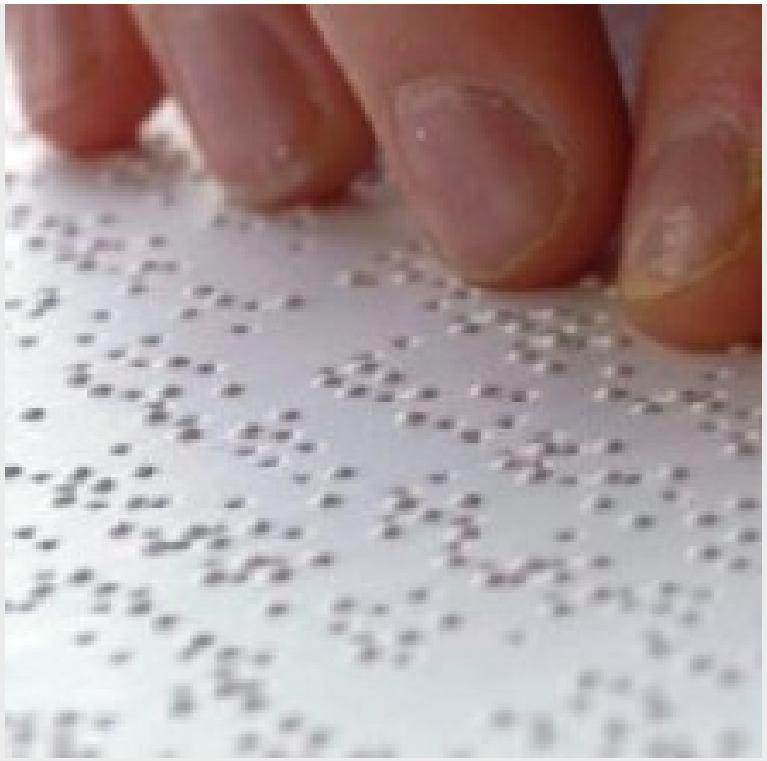
Purpose

- The situation for Braille users learning mathematics is not satisfactory
- Digital platforms are not automatically accessible for people with blindness
- Need for a design for multimodality, both regarding the architecture and the interface
- With the point of departure in the Nine Laws of Cognition we focus on complex content such as mathematics and how it could be accessible for Braille readers
- The aim is to identify the functionality and the technical infrastructure needed to make the design of a truly usable learning environment possible

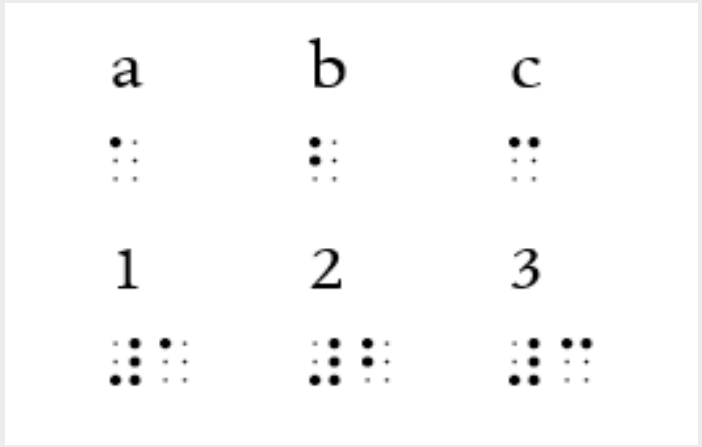
How many?

- Swedish children aged 0–19: approximately 2 500 have a visual impairment, hence it is not common
  - Approximately 2/3 of them have additional impairments
- During the latest decades approximately 10 children/year in Sweden become braille users
- A growing number have a visual impairment due to an extremely premature birth (which may cause CVI, cerebral visual impairment)



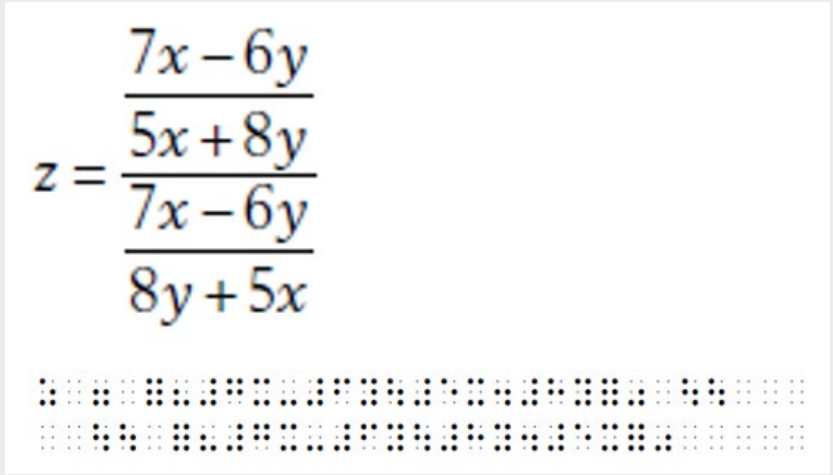
Braille

- A tactile writing system that gives direct access to the written language
- Louis Braille (1809–1852)
- Created around 1825



Braille

- Braille consists of a cell containing six dots that could be combined in 64 different ways
- Braille has specific combinations of dots representing the various letters in the alphabet
- Braille cell combinations are not based on letter sign similarities but on other principles
- Braille needs to be considered as a unique writing system with its own writing principles



Mathematics in Braille

- Mathematics is complex and denoting or involving numbers or quantities containing both a real and an imaginary part.
- Expressions are often notated in print in a two-dimensional form, e.g., fractions and square roots. For a Braille reader, all this will be presented in a linear form.

Cognitive processes

- Nine Laws of Cognition illustrate how the mind gets involved as we navigate the world and interpret our environment (Tversky 2019). Eight of them are relevant for braille readers learning mathematics.
    1. There are no benefits without costs.
    2. Action molds perception.
    3. Feeling comes first.
    4. The mind can override perception.
    5. Cognition mirrors perception.
    6. Spatial thinking is the foundation of abstract thought.
    7. (The mind fills in missing information.)
    8. When thought overflows the mind, the mind puts it into the world.
    9. We organize stuff in the world the way we organize stuff in our minds.

1. Their is no benefit without cost

- The lack of one sense will causes challenges for a person, to make something accessible means that some effort is needed.
- To make a platform or a software accessible for a Braille reader means it could be usable with a Braille display or by synthetic speech.

2. Action molds perception

- Perception is not something that comes to us, we need to be active to perceive the environment.
- To be able to perceive the Braille letters motion is needed, one must move the fingertips on a display or a printed sheet to recognize the letters.

3. Feeling come first

- The feeling is often affected by what supports or hinders the use of a platform or a software.
- By designing for accessibility there is chance that the user feels addressed and by that motivated to take the effort to use the platform.

4. The mind can override perception

- We experience the world from our own bodies, that involves previous experience and memory that are involved in all perception.
- For a person with blindness, it is not always that they perceive what they touch or hear, since they are occupied by previous experience that works as a grid between them and the environment.

5. Cognition override the perception

- What we see, touch, and hear, influences our mental images, and our mental images influences the perception of the environment.
- Like sighted people, blind people learn to touch and hear continually.

6. Spatial thinking is the foundation of abstract thought

- Spatial thinking includes logic, something that could be communicated.
- Platforms and interfaces aiming to support people with blindness need to have a spatial and hierarchical structure that follow the logic of the content and the intended use.

8. When thought overflows the mind, the mind puts it into the world

- Like sighted people, blind people need to take notes, or jotting in textbooks to remember important parts.
- Printed Braille books do not allow jotting in the book, the notes need to be made separate as text or voice memos.

9. We organize stuff in the world the way we organize stuff in our minds

- To make complex content accessible such as mathematics and science for people with blindness, a user involvement is necessary.

Multimodality

- We perceive and understand our surroundings through our senses.
- It is important to stimulate and activate, for example, a child with blindness so that he or she really utilizes touch, smell, and hearing.
- Auditory input, such as read out text or synthetic speech, is common for people with blindness, and function as a support or supplement to Braille.
- When studying mathematics, a combination of braille and audio is necessary since it requires too much cognitive load to use audio only.

Usability and technical development

- Daisy is an international standard designed to be a complete audio substitute for print material and is specifically designed for use by people with blindness, low vision, and dyslexia. Based on the MP3 and XML formats, the Daisy format has advanced features in addition to those of a traditional talking book
- MTM (Swedish Agency for Accessible Media) is furthermore planning to use EPUB 3 as distribution format for talking books (with text and recorded sound). The present distribution format is called Daisy 2.02. This change has been prepared and expected for many years and is a part of a global shift in electronic publishing and in accessible publishing for persons with print disabilities.

A Pilot study of EPUB 3

- The need to fulfill certain prerequisites before introducing EPUB 3 as a distribution/consumer format were observed, including the following:
  - EPUB 3 reader software and screen readers must function well together. Information must be sent to the refreshable braille display and to the speech synthesis equally.
  - Access to original pagination/page numbering when available to enhance navigability.
  - Skippability or escapability, i.e. the possibility to escape from certain content such as tables, and to continue to read the main content.

EPUB 3 and mathematics

- Concerning mathematics in EPUB 3, the pilot study stated that, since the EPUB 3 specification allows the embedding of mathematical markup with MathML (Mathematical Markup Language), it is very likely the best choice to handle mathematics in digital master files.
- The need for development of support for the Swedish language for MathML was therefore highlighted, both for output in braille and in speech synthesis.

Usability challenges for Braille users learning mathematics (1)

- Current learning materials produced in Sweden for Braille users contain mathematic content in the ASCIIMath format, a practical and useful choice allowing the Braille users to write mathematical expressions by themselves
- The situation for Braille users learning mathematics is not at all satisfactory though:
  - Braille users practice a format not in use by teachers or sighted peers
  - The Braille standard for writing mathematics on paper is very much different from reading and writing digitally in the ASCIIMath format
- Braille users need to be acquainted with several alternative mathematical formats, which is not expected from their sighted peers – their cognitive load is hence comparatively heavier

Usability challenges for Braille users learning mathematics (2)

- The possibility to use Braille as input, to write mathematical expressions by using a Braille keyboard, is not present
- Neither is the possibility to choose the paper Braille standard for mathematics as output format
- Nor is speech input or output for Swedish available

Usability challenges for Braille users learning mathematics (3)

- The vision is a complete, flexible, and usable learning environment for Braille users learning mathematics by providing all complementary input and output possibilities that are relevant for Braille users, for the individual to choose from
- Required input modes: Braille keyboard, speech, ASCIIMath and MathML
- Required output modes: refreshable Braille devices, speech, Braille embossers, ASCIIMath, MathML, and SVG for images

What is needed for people with blindness to have access to complex content in Braille

- The possibility to write in Braille, to input Braille
- Conversion between Braille and MathML/ASCIIMath/LaTeX
- The possibility to output Braille to various devices including embossers
- Conversion between MathML/ASCIIMath/LaTeX and Braille needs to be developed and/or adapted to various languages, such as Swedish
- An individual choice in input and output settings
- Software that can display mathematics visually using MathJax and HTML5, both within and outside the EPUB 3 context
- Software that can display mathematic content written by Braille users
- Interaction with refreshable Braille devices that are able to produce images and graphs

Conclusion

- More knowledge is needed when designing the interfaces for a future learning environment for Braille users learning mathematics.
- What we are aiming at, is to identify the functionality and the technical infrastructure needed to make the design of a truly usable learning environment possible.
- Central is the possibility to use Braille as input and output mode, to switch freely between the available input and output modes, and the possibility to make these choices individually.
- Crucial for the motivation in Braille users to learn mathematics is an interface that is designed with regard to cognitive aspects and taking available modalities into consideration, that is touch and hearing.

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