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Chapter 2

Matilda: a typeface for children with low vision

Ann Bessemans

Due to the low quality level of visual input they receive in the form of printed text, visually impaired beginning readers are at a disadvantage in comparison to their peers. In the past, typography has often been regarded as a useful instrument to improve the legibility of the printed reading material that is being offered to children with low vision. However, the legibility research that was at the base of this conception was not always of good quality. In cognitive science for example, many efforts were made that were methodologically correct, yet the test material (typefaces) was unrealistic. On the other hand, typographers themselves introduced many typefaces that were supposed to improve legibility, but the reasoning behind them was hardly ever sufficiently methodologically supported. Moreover, most legibility research focused on people with low vision in general, ignoring the fact that visually impaired children constitute a very particular group with specific issues. This PhD research project approached the issue of legibility for visually impaired beginning readers from a design context. The research is an attempt at bridging the gap between the font designers and the cognitive scientists studying the legibility of letter characters. In the development of the test material, the focus was on parameter design. Parameters are shape characteristics that can be isolated within the same type. Starting from two existing types (one serif, one sans-serif), typefaces were designed based on five parameters that explored the balance between homogeneous and heterogeneous in both form and rhythm. Based on legibility research with test material that conforms to both the scientific and the typographic knowledge in this field, a typeface is proposed that provides support for the target group of visually impaired children in the first stages of the reading process.

1.1 Introduction

Reading is done without consciously recognizing letters [Warde, 1956; Unger, 2007]. Nevertheless letters constitute an important aspect of determining legibility [Rayner and Pollatsek, 1998]. Letters need to be decoded in order to obtain meaning. Reading is a complex, cognitive and fast process. Children having serious problems with reading are at an increased risk to end up in a cycle of failure [Stanovich, 1986; Wolf, 2007]. When reading is a slow and cumbersome process, it will have consequences for cognitive behavior and motivation. A person whose reading process is im-

peded is less able to develop both intellectually and socially. Because most of the process of learning to read is finished after the age of nine it is important that children who encounter difficulties are supported in the initial stages of this process [Stanovich, 1986; Marquet *et al.*, 2006].

Visually impaired children with no additional disorders do not have problems with reading comprehension, spelling or accuracy. Therefore the reading problems of children with low vision are (initially) visual and not cognitive [Gompel *et al.*, 2003; Gompel, 2005]. A visual impairment has a direct impact on technical reading skills.

Due to the low quality of visual input they receive in the form of printed text, beginning visually impaired readers are at a disadvantage in comparison to their (visually unimpaired) peers. The reading process is disturbed due to a reduction in visual input [Gompel *et al.*, 2003; Gompel, 2005]. Children with a visual impairment have problems with the decoding of words, the deciphering of visual patterns, and the recognition of letters. Because their decoding is hampered, the reading speed is lower, which eventually can lead to cognitive problems necessitating a transfer from regular to special education. To improve visual input, a lot of attention is given to optical reading aids and the use of large print. Large print is often seen as a quick fix to show that efforts have been made for the visually impaired. Research has shown that large print books are not effective for the technical reading process for most children with low vision [Lovie-Kitchin *et al.*, 2001; Corn *et al.*, 2002].

1.2 Typographic research and legibility research

In the past, typography has often been looked upon as a useful instrument to improve the legibility of printed reading material that is being offered to people with low vision. However, legibility research efforts are not always of good quality. In the case of cognitive scientists this is all too often caused by inadequate domain knowledge of typography, pointed out by Spencer [1969], Dyson [1999], Lund [1999] and Bessemans [2012]. This can lead to the use of incorrect terminology, poorly designed letters, poorly motivated and incorrect choice of text material. For the designers, this is due to an intuitive way of approaching legibility research [Dyson, 1999; Lund, 1999; Bessemans, 2012]. Typographers rarely do empirical research. Very few attempts are made by typographers to test their de-

signed material on their target group. They portray their 'findings' as truism, but these lack any scientific validation.

Many legibility studies focusing on the influence of design, both within cognitive science and within the design world, lack internal and/or external validity. Figure 1 shows test material illustrating a common external validity problem. The material is carefully constructed by manipulating isolated parameters (like heaviness of serifs, letter width, letter height). This results in high internal validity. But the external validity is very low. These letters are not considered real typefaces used in everyday life. Figure 2 shows test material illustrating a common internal validity problem. The test material could be present in real life, which means that the external validity is high. However, effects on legibility cannot be attributed to single design parameters. Several design parameters (or even a combination) can influence the legibility effect. For example a difference in legibility between Helvetica and Times New Roman cannot be attributed solely to the serifs as there are other differences between the two types. Therefore the internal validity is rather low. Design parameters are design characteristics within the same font that can be isolated and can be manipulated independently of each other. A design parameter can therefore be related to the internal and external validity.

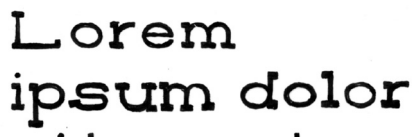

Figure 1: (Left) An example of a common external validity problem. Examples of such material can be found in: [Liu and Arditi, 2000; Arditi, 2004]

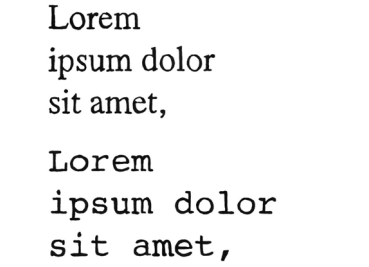

Figure 2: (Right) An example of a common internal validity problem. Examples of such material where comparisons are made between typefaces can be found in: [Mansfield *et al.*, 1996; Woods *et al*., 2005]

Moreover, most legibility research has focused on adults with low vision, ignoring the fact that visually impaired children constitute a very particular group with specific issues. Both the fact that their reading pro-

cess has just started, as well as the fact that their visual impairment is not caused by ageing, makes it difficult or even impossible to simply transfer results. It makes sense to hypothesize that the elderly are more aided by a macro level of typography like the layout of a page or book or even a bigger type size which slows down reading but is more comfortable [Bouwhuis, 1993].

1.3 The term legibility

Another problem within the existing legibility research is confusion regarding the term legibility. Many different groups of people (e.g. typographers, linguists, educationalists, ergonomists, psychologists, etc.) use the term and give it a personal related meaning without explicitly explaining it. This explanation is of importance in order to make legibility studies comparable. Within this research legibility is the ease with which visual symbols are decoded [Bessemans, 2012]. This definition arose from dictionary descriptions of reading. Reading means: transposing visual symbols and converting them into linguistic meanings. To concisely define the term legibility, attention goes to the two global and successive steps that occur when reading: decoding and the acquisition of meaning, or the sensoric and the cognitive aspects of reading (see Figure 3). Decoding or the sensoric aspect in reading is the conversion of the purely visual representation of words (which may not yet relate to the meaning of these words in beginner readers). The definition of legibility used in this study is clearly related to this first sensoric aspect of reading and thus to decoding problems of children with low vision.

1.4 Design methodology applied

Comprehensive legibility research within my own study takes into account a clear definition of legibility and a combination of both scientific methods and typographic practice. A designer-researcher is able to combine these two and thus guarantee the internal and external validity of the test material. The materials of the design research are systematically constructed. The design is the point of focus throughout the research. The methodology starts with the context that is shaped by theoretical research (consisting both of scientific and typographic matter) and practical work

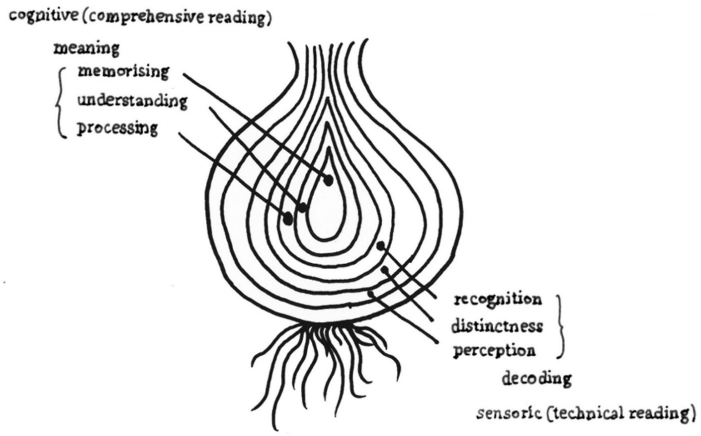

Figure 3: An onion model explaining the sensoric and cognitive aspects within reading.

from other designers (mainly typefaces). This context will lead to an initial design that ultimately results in test fonts. These test fonts are used within legibility studies (see 1.5). In turn, the results of the legibility studies provide motivation for a second type design that will eventually lead to the development of a special font for children with low vision. Using this global framework, this study starts with an explicit definition of legibility, and uses methods of measuring that have both internal and external validity. The output is an improved insight into the nature of legibility and some practical guidelines in the realm of type design.

During the process of designing the test typefaces the focus was on parameter designs. Departing from two existing typefaces (serif DTL Documenta and sans-serif Frutiger) a number of derived typefaces were designed with five different parameters: (1) variable x-height; (2) conventional contrast; (3) unconventional contrast; (4) direction; (5) letter width (see Figure 4).

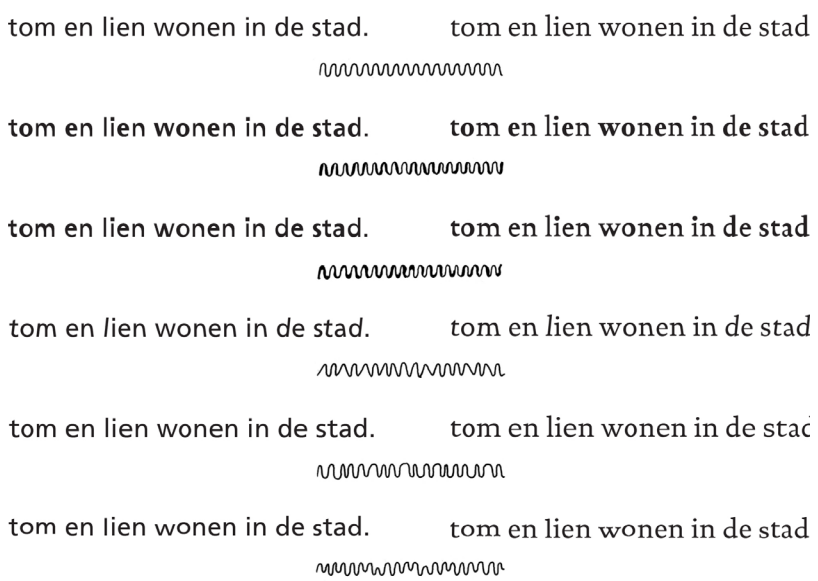

Figure 4: The test fonts (sans serif and serif) with their illustrated rhythm. From top to bottom: the basic fonts Frutiger and DTL Documenta; parameter conventional contrast; parameter unconventional contrast; parameter direction; parameter letter width; parameter variable x-heights.

1. Variable x-height: By changing the x-height and the ascender and descender height of the letters, this design parameter induced a lot of heterogeneity, both rhythmically and in terms of letter form.
2. Conventional contrast: This parameter adds contrast to the letter in a conventional way. Certain letter parts were emphasized in a conventional manner. This parameter mainly induced heterogeneity in terms of letter forms.
3. Unconventional contrast: This design parameter emphasized the most distinctive character parts within the letters. This induced in particular the heterogeneity of letter forms (because of less symmetry).
4. Direction: Within this parameter, more heterogeneity was induced within rhythm by playing with the directions of the letter strokes.
5. Letter width: Within this parameter, more heterogeneity was induced within rhythm and letter form by varying the letter widths.

The five parameters were used to examine the balance between homogeneous and heterogeneous in both form and rhythm. The heterogeneity with regard to the letter shape can be illustrated by making related letters less similar (see Figure 5). The heterogeneity with regard to the rhythm of the font can be illustrated by a more irregular stripe pattern which is formed by the vertical letter strokes.

Using the concepts of homogeneity and heterogeneity we can say that in general sans serif typefaces are homogeneous within their letter forms (because of possible mirroring) and heterogeneous within their rhythm (see Figure 6). With serif typefaces it is the other way around (certainly for serif typefaces based on the 20th century model): they are heterogeneous within their letter forms (the serifs and contrasts make mirroring impossible) and homogeneous within their rhythm. Theoretical and practical insights concerning legibility of material for low vision children pointed in the direction of more heterogeneity. Notice that we never tested very extreme forms of heterogeneity.

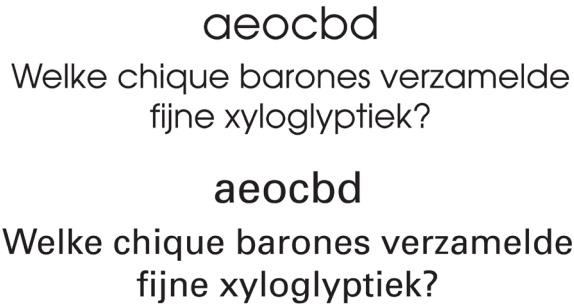

Figure 5: Illustrating the heterogeneity within letter shape. Top: a geometrical sans serif. Bottom: a humanistic sans serif.

1.5 Quantitative and qualitative legibility research

The typefaces were tested by means of experimental (quantitative evaluation) and subjective (qualitative evaluation) legibility research. Both children with good eyesight and low eyesight were selected in order to study the reading skills and reading experiences in visually impaired children. In the study 110 visually impaired children with no additional disorders participated. They were recruited thanks to the cooperation of centers for

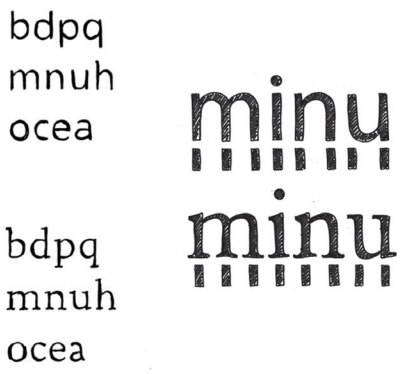

Figure 6: Illustrating letter and rhythm heterogeneity. The heterogeneity within the letter shape lies in the serifs and the contrast of the serif typefaces. The heterogeneity within the rhythm lies within the rhythmical pattern formed by sans serifs.

the visually impaired in Belgium and the Netherlands. Also 54 normally sighted children participated in the study and were recruited by regular schools. All readers were five to ten years old.

A psychophysical method was used in the test. Children were presented pseudowords[a,b] in the test typefaces on a computer screen for a short period of time and asked to read aloud the word seen (see Figure 7). The read words were typed and the number of word (letter) reading errors was counted using the software Affect [Spruyt *et al*., 2010].

In order to allow for differences in error rates between different type faces, the words were followed by a mask and the time in between the word and the mask and/or the word exposure time was adjusted for each child in order to obtain a 50% chance of recognition. This was done in an initial testing phase. Hence, every child had an individual duration at which words were presented. The children who were better at recognizing

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a Pseudowords were used because phonological rules and conventions within the letterforms remain, while semantic knowledge and the influence of context are excluded.

b 100 pseudowords were created with an equal amount of letters. These pseudowords were used within each parameter and the basic fonts. The software controlling the experiment selected and mixed at random an equal amount of words within the design parameters. Simultaneously the fonts (basic and derived) were chosen at random by the software (Affect).

words were presented with words for a shorter duration. Then, in the main test, 6 sessions of 60 pseudowords were presented to each child with the child's specific word-duration. Within each session there were 3 breaks to ensure concentration. The statistical analyses were performed on these data.

The effects of the design parameters were measured using statistical analyses based on a General Linear Model (GLM) with repeated measures. The GLM calculates the extent of the connections between a dependent variable (e.g. percentage of words read correctly) and some independent variables (e.g. the different design parameters). Repeated measurements allow you to take multiple observations within a subject (the various sessions of each child can be included within the analysis, taking into account between-subject variability). The GLM identifies those variables that are reliably influencing legibility. Several analyses with percentage correctly read pseudowords as the dependent variable were done: 1) global analyses; 2) analyses within each group of children (low vision and normal); 3) analyses limited to words where at least one letter was correct; 4) analyses in relation to reading level; 5) analyses contrasting Documenta vs Frutiger; 6) analyses for different types of visual problems.

In the subjective part of the study, reading experiences of children who read the test typefaces were examined. The children were (individually) asked to rank the test material, 12 fonts, by the legibility[c] of the fonts (see Figure 8). The children were interviewed about which factors played a role in their subjective judgement by means of dialogue. The feedback and the interaction with the children were of great importance for the design of the final typeface. In contrast with this way of working, a type designer very rarely gets immediate feedback from his readers. Type designers have always been very far behind the frontline when it comes to contact with the readers. In this case there was direct feedback between the readers and the type designer.

The effect of the design parameters on legibility using the subjective method was measured using Kendall's concordance coefficient W. When this coefficient is high, this means that the ranking as observed is a reliable one, i.e. children agreed on the ranking.

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c The children were asked which fonts read the best for them.

Figure 7: Experimental legibility research (quantitative).

Figure 8: Subjective legibility research (qualitative).

1.6 Results

A remarkable finding from the objective legibility research is that children with normal vision read with reliably fewer errors when the serif typeface DTL Documenta was used, rather than the sans serif Frutiger. This result is somewhat surprising because children (especially beginning readers) mainly read with a sans serif in primary school. Zuzano Licko's [1990] well-known quote: '…the readers read best what they read most' is thus jeopardized, certainly for beginning readers in the age group of five to ten years old. The teachers' belief that letters for beginning readers should look as simple as possible and should reflect handwriting is falsified by this study. In visually impaired children the difference in reading accuracy of the two typefaces is less pronounced. During the reading (decoding) process non-visually impaired children appear not to be hampered by a homogeneous rhythm, but rather by a homogeneous form. The children with low vision however, seemed to be hampered more, and in particular, by a homogeneous rhythm. Within the DTL Documenta font set (the basic font with a homogeneous rhythm) the design parameters – rhythm[d] and direction – that made the rhythm the most heterogeneous, had the most positive effect on legibility (in terms of decoding). It appears that for visually impaired children a more irregular rhythm is beneficial for their reading. Also it may be that a certain degree of formal heterogeneity offers support (as we saw with the normally sighted children).

Within the subjective legibility research, the analysis of the rankings showed no significant results. However, the dialogue with the children contained a lot of relevant information. The subjective legibility research results showed a rather early conditioning with daily reading material in beginning readers. Children associated sans serifs with school and considered them to be writable; serifs they associated with literature (e.g. books and newspapers) and they considered them to be difficult to reproduce themselves. The non-visually impaired children generally perceived the most conventional typeface as being the most legible one. Amongst the visually impaired children this was not always the case. Some of the

d It became clear that the difference with respect to the design parameter rhythm and the basic font is not seen by most of the beginning readers. This parameter can therefore be useful for practical use because it induces legibility while remaining invisible.

children appeared to experience social pressure to choose a normal letter. They were reporting that classmates would laugh at them if they chose a strange looking font to read.

1.7 Matilda

Starting from the results, together with my own understanding, knowledge, intuition and ideas as a design researcher, a typeface called Matilda[e] was designed that is able to provide support for the target group of visually impaired children in the first stages of the reading process. Matilda should be seen as a tool for supporting reading, not as the solution to reading problems.

The new typeface is similar to the basic fonts DTL Documenta and Frutiger in terms of letter width and text color (see Figure 9). Matilda is based on a serif typeface, in order to reduce the gap between the reading material for non-visually impaired children and those with low vision. Furthermore compared to the sans serif font Frutiger, the design parameters within the DTL Documenta font set had the most positive effect on the decoding skills for children with low vision.

The main characteristics of Matilda are wide, open and round letters which are intended to have a friendly feeling (see Figure 10). The letters are dynamic and solid, constructed and organic. The letters are built on a rather stable and vertical axis. The curves are open, the serifs are asymmetric, convex and concave. There are ball terminals to emphasize the letter terminations to augment its individuality and distinctiveness. The low contrast in the letters is necessary to easily enlarge or reduce text. If children with low vision are reading in different contrasts/colors (which they often do on computers) the letters need to remain very clear. Matilda does not have a very large x-height. The ascenders and descenders provide enough room for diacritics.

e Named after the book 'Matilda' from Roald Dahl (1988).

'Zit je goed, Sofie? Voor de rest van de cursus is het van belang dat je inziet dat sofisten echte filosofen waren, die hun plaats verdienen in de geschiedenis van het menselijk denken. De sofisten lieten zich voor hun werk betalen, omdat ze niet zoals Plato konden rekenen op een rijkelijk inkomen. Het waren mensen met een ruime belangstelling voor intellectuele en ethische problemen, die hun kunde in dienst stelden van hun studenten. Dergelijke sofisten zijn de hele geschiedenis door gekomen en gegaan. In zekere zin waren zij de eerste humanisten en onafhankelijke onderzoekers. Met leraren en betweters, die ofwel dik tevreden zijn met het weinige dat ze weten of opscheppen dat ze van een heleboel dingen verstand hebben, waar ze in werkelijkheid geen snars van begrijpen, hebben ze dus niks van doen...' !,?.

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Figure 9: Comparison of the text color and letter width between Matilda (top), DTL Documenta (middle) and Frutiger (bottom).

Figure 10: Design features of Matilda.

Matilda is in full development and a growing type family (also ready to test within new legibility research). The typeface includes a serif, an italic, and a bold (see Figure 11). Matilda is also extended by the design parameters that were most helpful to improve the decoding process of children with low vision. These are the parameters rhythm (see Figure 12) and direction (see Figure 13)[f]. More research will be done because it would be interesting to know how the degree of rhythmic heterogeneity affects legibility. Also the outcome of interaction effects such as the combination between the parameter letter width and direction would give more insight into legible fonts for children with low vision (and human perception as more information is revealed about the sensoric aspect when reading).

f Emphasizing letter parts seems to be helpful for visually impaired children at the lowest reading level.

Figure 11: Matilda Regular, Bold & Italic.

1.8 Conclusion

When legibility is explicitly defined and linked to the reading problems of the target group, methods of measuring legibility become clear while maintaining internal and external validity. It becomes clear that letters influence legibility and that results can be translated into a type design. A design researcher plays an important role in such legibility research.

This research highlights the importance of exploring the balance between homogeneity and heterogeneity. The design research gave clues to design parameters that can successfully improve legibility for low vision children by inducing rhythm heterogeneity. My future aim is to gain more insight into the legibility of printed matter by studying stripe patterns within words during reading, link these to spatial frequencies when reading and translate this information into practical designs. The new envisaged research wants to investigate to what extent the rhythm and spatial

tom en lien wonen in de stad.
ze wonen vier hoog.
ze hebben een hondje, woef.
tom speelt met zijn bal in de kamer.
woef springt wild naar de bal.
pats! de bal vliegt recht op de vaas af.

Figure 12: Matilda Rhythm.

tom en lien wonen in de stad.
ze wonen vier hoog.
ze hebben een hondje, woef.
tom speelt met zijn bal in de kamer.
woef springt wild naar de bal.
pats! de bal vliegt recht op de vaas af.
'tom maakt de vaas stuk', roept zus.

Figure 13: Matilda Direction.

frequencies within a typeface can affect legibility for normal and poor readers (e.g. low vision readers). This is in line with the findings of my doctoral dissertation where disturbed stripe patterns within words resulted in better decoding skills (and thus legibility) for those with a less developed perceptual system.

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