The Economy Of Typography (the Arrangement or Mode of Operation of Typography)

Jacqueline Raftery
Technological University Dublin

Follow this and additional works at: https://arrow.tudublin.ie/appamas

Part of the Art and Design Commons

Recommended Citation

This Theses, Masters is brought to you for free and open access by the Applied Arts at ARROW@TU Dublin. It has been accepted for inclusion in Masters by an authorized administrator of ARROW@TU Dublin. For more information, please contact yvonne.desmond@tudublin.ie, arrow.admin@tudublin.ie, brian.widdis@tudublin.ie.

This work is licensed under a Creative Commons Attribution-Noncommercial-Share Alike 3.0 License
The Economy of Typography

(The arrangement or mode of operation of typography)

Jacqueline R. Raftery
Award: MPhil

Dublin School of Creative Arts,
Dublin Institute of Technology.

Supervisor: Dr. Noel Fitzpatrick
August 2016
**Abstract**

*The Economy of Typography*

(The arrangement or mode of operation of typography)

The thesis will show that the current research into legibility and readability regarding certain aspects or characters of type is incomplete, and will demonstrate what further research is necessary to complete the analysis of these aspects or characters in the economy of typography in continuous text.

Chapter 1 will show that the development of reading depends on the legibility of the typography and characters ‘recognizing patterns, planning strategy, and feeling’ in other words reading and writing are interdependent all depend in some part on the construction of the characters and their relationship to each other. It will also show that readable writing is desirable and important for the reader’s sake.

Chapter 2 will deal with the practical presentation of the characters of what the reading public read, and the role played by legibility and readability of typography in conveying their message. Printers and designers will also have a working knowledge and experience of legibility and readability which is incorporated into typography presentations, and this also is taken into account in chapter 2.

Chapter 3 reviews the criteria and methods used in typography readability and legibility research. The research will show that readability is the ease with which the eye can absorb the message and move along the line, and legibility is based on the ease with which one letter can be identified from another.

Chapter 4 entitled Analysis and Recommendations concludes the thesis with a summary of chapters 1, 2 and 3 before presenting a comparative analysis of current research into legibility, with particular emphasis on misreading or misrecognition of characters, and provides illustrations of the conclusions reached by way of bar chart and tables.

Appendix One of the thesis contains a comprehensive list of the research into legibility and readability. Appendix Two contains the graphics of Benjamin Sherbow showing typography layout supportive of type spacing matters discussed in chapter 2. The thesis has an extensive bibliography of the works referred to throughout the thesis.
I certify that this thesis which I now submit for examination for the award of M.Phil., is entirely my own work and has not been taken from the work of others, save and to the extent that such work has been cited and acknowledged within the text of my work.

This thesis was prepared according to the regulations for graduate study by research of the Dublin Institute of Technology and has not been submitted in whole or in part for another award in any other third level institution.

The work reported on in this thesis conforms to the principles and requirements of the DIT's guidelines for ethics in research.

DIT has permission to keep, lend or copy this thesis in whole or in part, on condition that any such use of the material of the thesis be duly acknowledged.

Signature
Candidate
(D jacqueline Raftery)

Date: 28-8-2016
Acknowledgements

In the course of my work on this study I have had the wholehearted assistance and support of various people, and it now gives me great pleasure to be able to thank them for their help.

I am extremely grateful to my supervisor, Dr. Noel Fitzpatrick, Dean of Graduate School of Creative Arts and Media, and Head of Research at the School of Art, Design and Printing, Dublin Institute of Technology, for his support and encouragement during the course of researching and writing this thesis.

I wish to thank my parents, John and Peg, and my family, and also my friends for their support and assistance whenever required.
Table of Contents

Title page ................................................................. i
Abstract ........................................................................ ii
Declaration .................................................................... iii
Acknowledgements ...................................................... iv
Table of Contents ......................................................... v
Table of Figures and Tables ............................................. viii
Research Question ......................................................... xii
Introduction ................................................................... xii

Chapter 1: Reading and Writing

Introduction.................................................................. 1
The story and science of the reading brain ..................... 1
The invariance problem ............................................... 8
Scriptura continua ...................................................... 10
A new word order ........................................................ 12
Characters and letters and how language works .............. 12
Codex a change in the way books were produced ........... 18
Spread of reading and growth of literacy ....................... 20
Objection to the technology of writing ......................... 21
The media of the Net ................................................... 23
Conclusion ..................................................................... 28

Chapter 2: Legibility and Readability

Introduction .................................................................. 30
Legibility from a practical basis .................................... 31
Roman type ................................................................. 32
The difference between type, roman type,
alphabet, letters and words ....................................... 33
Differences between ‘alphabet’ and ‘letters’ .................... 34
The effect of colour on print ......................................... 38
Historical research into print based typography ............. 40
Layout and typographic design ..................................... 44
Example of typographic design going wrong
(or not using the right type) ......................................... 46
Chapter 3: Criteria and Methods used in Typographical Readability and Legibility Research

Introduction ................................................................................................................. 71
Printed text .................................................................................................................. 77
Factors used to study typography in legibility and readability .................................. 77
Research with eye-movement and legibility ................................................................. 78
The visibility method ................................................................................................. 82
The distance method ................................................................................................. 83
The right type ............................................................................................................ 88
The short-exposure method ....................................................................................... 96
The Focal Variator ..................................................................................................... 97
The Blink test ............................................................................................................ 98
The speed of reading method .................................................................................... 100
Chapman Cook Speed of Reading test ..................................................................... 102
Tinker Speed of Reading Test .................................................................................. 103
Eye movement while reading ................................................................................... 105
Methods and instruments that were used to study different aspects of reading ......... 108
Screen typography versus Printed typography ....................................................... 111
Birth of computers .................................................................................................. 111
The computer memory and the human memory ..................................................... 112
Research into the difference of reading from paper and reading from screen .......... 112
Research of silent reading from screen versus paper .............................................. 113
Comprehension studies in relation to reading on screen versus paper .................. 115
Serif versus sans serif which is more legible .......................................................... 117
Table of Figures and Tables

Chapter 1: Reading and Writing

Figure 1: Three Reading Brains .................................................................2
Figure 2: Sumerian writing: example of an early writing system ..............5
Figure 3: A comparison between Proto-Sinaitic, Phoenician, and Greek alphabets .................................................................6
Figure 4: ‘The Proper Sounds for the Instruction of the People,’ or the ‘Hunminjeongeum’, describes the new and innovative script for the Korean language as promulgated by King Sejong the Great in 1446 .................7
Figure 5: The invariance problem ...............................................................9
Figure 6: Example of scriptura continua ..................................................10
Figure 7: Epitaph of C. Aurelius Parthenius, dated end of 1st century-
beginning of 2nd century AD ................................................................12
Figure 8: The Book of Mulling, 2nd half of the 8th century .....................13
Figure 9: Papyrus manuscript of the gospel of John from an early copy of the New Testament in Greek ..............................................19

Chapter 2: Legibility and Readability

Figure 10: Shows Univers type family to illustrate colour of text ............38
Figure 11: Reproduction of graphic shows the effect of colour from Benjamin Sherbow Making Type Work published 1916 page 86 ..........39
Figure 12: ‘Metal type with kerns makes all the difference in the spacing between certain character pairs, such as ‘rf’, ‘fe’, and ‘ct’ (lower) .......49
Figure 13: Showing parts and names of metal type ..................................50
Figure 14: Graphic showing the Troy and Chaucer type by William Morris in 1897 .................................................................52
Figure 15: Samuel Hayes’s Practical Treatise on Trees showing lowercase s looking like a lowercase f ......................................54
Figure 16: Headings from the “Ship of Fools”
Latin translation printed in 1497 ...........................................................54
Figure 17: Reproduction of graphic shows the effect of wide word spacing, closer spacing in text .........................................................60
Figure 18: Shows 12pt Times top paragraph set solid, second paragraph is set in 1.5 line spacing (18 point leading) and the third paragraph is set in double line spacing (24 point leading).................................62

Figure 19: Verdana characters showing the large x height and open counters spaces .................................................................65

Figure 20: The terminology relating to different parts of a type character ........66

Figure 21: Shows some display typeface set in 12pt.................................68

Chapter 3: Criteria and Methods used in Typography Readability and Legibility Research

Figure 22: Patents drawings for M. Luckiesh, F. Moss 1939 apparatus for measuring visual efficiency. ......................................................76

Figure 23: The upper half of letters play a major role in deciphering ..........80

Figure 24: Typefaces used in Barbara E. Roethlein research..........................86

Figure 25: The type was set in in Janson text
9pt on 11pt leading. ........................................................................91

Figure 26: The type was set in in Cheltenham Bold text
9pt on 11pt leading. ........................................................................92

Figure 27: The type was set in Franklin Gothic Heavy Italic text
9pt on 11pt leading. ........................................................................93

Figure 28: An Electronic Tachistoscope. ................................................97

Figure 29: An example of the Speed of Reading Test–Preliminary Drill (6 printed unit arrangement) designed by J. C. Chapman in 1923 .........................................................103

Figure 30: Saccadic eye movement ........................................................106

Figure 31: PC Sales of leading companies 1991-2010.............................116

Figure 32: The ‘Task’ explains the task and presents the matrix and the matrix search task.........................................................125

Figure 33: ‘Experiment 1: Roman letters in experts’ states the number of subjects (17), the different conditions examined (baseline, regular and mixed), the amount of typeface used (5) and the amount of targets per matrix (3, 4 and 5)..............................125

Figure 34: Perceived typeface legibility ................................................130

Figure 35: Percentage of typefaces chosen as first or second preference choice .................................................................130
Chapter 4: Analysis and Recommendation

Table 1: Summary of tables in chapter 4 ................................................................. 139
Table 2: Data showing the number 1 ranked misread letter ................................. 140
Table 3: Summation of the most commonly mistaken letter reviewed by case (i.e. U/lc) ................................................................. 141
Figure 36: Histogram of most commonly misread letters ................................. 141
Figure 37: Top three most common misread letters,
Ranks 1-3 given equal weighting ................................................................. 142
Figure 38: Pareto of top three misread letters (note a is unnaturally inflated (it is more with the t, g, e grouping)) ................................................................. 143
Table 4: Top misread letters (a excluded for reason already stated) ................. 144
Figure 39: Top three ranking compared with respect to serif and sans serif ...... 145
Table 5: All data rated by order and split between cases and serif .................. 146
Figure 40: All data with respect to uppercase and lowercase, serif and sans serif ................................................................. 146
Figure 41: Pareto review of all data, weighted according to ranking with uppercase and lowercase ................................................................. 147
Figure 42: Zoom on top of graph weighting according to rank with uppercase and lowercase ................................................................. 147
Table 6: All data sum of inverse rating by year and occurrence ignoring case ................................................................. 148
Figure 43: All data rated by year not showing case ................................................................. 149
Figure 44: Zoom on ten least misread letters by year not taking case into account, the characters are as follows but not in order – u, d, z, n, v, k, p, s, x, r ................................................................. 149
Figure 45: Pareto review of all data, sum of inverse rating viewed by year ..... 150
Figure 46: Review of all data, by year ........................................................................ 150
Figure 47: Top seven misread characters by year ......................................................... 151
Figure 48: Top misread characters per year ................................................................. 151
Figure 49: Frequency of misread letters, including upper/lower case and total, per year ......................................................................................... 152
Appendix Two

Figure 50: Page 86 from Benjamin Sherbow’s 1916 publication, *Making Type Work*, showing uneven colour, caused by uneven letter and word spacing. .............................................227

Figure 51: Page 88 from Benjamin Sherbow’s 1916 publication, *Making Type Work*, showing spacing and letter spacing. .........................228

Figure 52: Page 92 from Benjamin Sherbow’s 1916 publication, *Making Type Work*, showing word spacing. .....................................................229

Figure 53: Page 88 from Benjamin Sherbow’s 1916 publication, *Making Type Work*, showing the effect of different line spacing. ............230
Research Question
How is current research into legibility and readability regarding certain aspects or characters of type incomplete, and what further research is necessary to complete the analysis of these aspects or characters in the economy of typography?

Introduction
The thesis will show that the current research into legibility and readability regarding certain aspects or characters of type is incomplete, and will demonstrate what further research is necessary to complete the analysis of these aspects or characters in the economy of typography in continuous text. It may be said that: ‘Type is the formal expression of writing, and writing is the physical representation of language.’1 It is appropriate then that any such analysis of the dual concepts of legibility and readability should commence with an analysis of the interconnected concepts of reading and writing, the alphabet being a common factor between the two, and this is demonstrated in chapter 1 entitled Reading and Writing. Reading and writing provide a system of translating sound in a spoken language into symbols and characters by using the alphabet. A proper understanding of these symbols and characters also requires schooling and practice in typography. This schooling and practice depend on the legibility of the type and characters ‘recognizing patterns, planning strategy, and feeling’2 and all these factors depend on the construction of the characters and their relationship to each other, along with the recognition of groups or pairs of such characters and the layout of typography. The understanding of words and characters and the ability to make sense of them is where legibility and readability come into play.

The research in chapter 1 will show that the development of reading depends on the legibility of the type and characters ‘recognizing patterns, planning strategy, and feeling’ in other words reading and writing are interdependent all depend in some part on the construction of the characters and their relationship to each other. It will also show that readable writing is desirable and important for the reader’s sake. If it is not readable to the intended reader it does not fulfil its purpose. The reader must be the judge.3 Practice suggests that ‘we are what we read’4 and ‘you read best what you read

most\textsuperscript{5}, and this practice is the same for typefaces, be they printed or electronic type. Since the inception of communication with symbols and characters the need to make these characters legible and readable developed along with the use of the characters. It is also important to emphasise that legibility and readability are two separate and distinct concepts. Essentially, legibility deals with the design of the typeface; readability deals with the ease with which the eye can absorb the message and move along the line of text and/or the style of language used. ‘The readability has to do with how easy, difficult, interesting, or accessible its contents are, relative to the reader. When typography and other physical aspects are concerned, one speaks of legibility.’\textsuperscript{6} Legibility is then more concerned with the visual perception of typeface and layout.\textsuperscript{7}

Chapter 2 concentrates on an analysis of the dual concepts of legibility and readability and how they relate to reading and writing discussed in chapter 1. This analysis is also pertinent to the new technology and the reproduction of typography as they also present the designer with new problems due to changes in the way that type is presented to the reader by computers and tablets. While ‘many excellent typefaces from earlier periods are in most effective use today’\textsuperscript{8}, advances in current technology present new problems that differ from those in the past. The modern technical demands of high-speed and rotary presses, machine-made paper, and text on computer devices, present typography with different limitations, and these have to satisfy modern technical demands along with legibility.

The research in chapter 2 will deal with the practical presentation of the characters of what the reading public read, and the role played by legibility and readability of typography in conveying their message. The arrangement of type by designers (from scribes in Medieval times to present day designers), and printers (from Gutenberg and the incunabula to present day printing) is the public face of typography, and here also practice suggests that ‘we are what we read’\textsuperscript{9} and this practice presentation provides the source material for the researcher into legibility and readability. Printers and designers will also have a working knowledge and experience of legibility and readability which is incorporated into typographic contexts, and this also is taken into account in chapter 2. The typographic practitioner presents the reading public with the raw material and the

\textsuperscript{5}Margenthaler Linotype Company. \textit{The Legibility of Type} (Brooklyn, New York: Margenthaler Linotype Company, 1935), 34.


finished product for reading bearing in mind: ‘You read best what you read most’\(^\text{10}\), i.e. the familiarity with words, characters and the subject aid in the readability of a text. Thus, the typographic practitioner plays an important role in making typographic legacy and readable, and is a role that should be taken into account by any scientific research into typography.

Chapter 3 reviews the criteria and methods used in typography readability and legibility research. The research will show that readability is the ease with which the eye can absorb the message and move along the line, and legibility is based on the ease with which one letter can be identified from another. The research to date, by adopting the positivistic approach in relation to the dual concepts of readability and legibility, appears to have excluded or reduced to insignificance the variable factor involving human introspection or intuition. The positivistic approach adopted in the 19\(^{\text{th}}\) and 20\(^{\text{th}}\) centuries with the collection of empirical evidence involves presuppositions that there is an objective reality and that people/readers can identify this reality by symbols that can be accurately described and explained. With advances in technology it may seem ‘that old theories’ and ‘rules’ concerning legibility are outdated’\(^\text{11}\) but this observation is not completely true. For instance, Javal’s observation in the 1800s that the lower half of the word covered leaves the word legible still applies. While it is true to say that the technology is new the research will show ‘that old theories and ‘rules’ concerning legibility have remained the same. Also, even though the technology for reading has changed the methods involving speed of reading and comprehension have remained the same. Miles Tinker refers to this method of speed reading ‘after reviewing all the literature in the field, that speed-of-reading performance is one of the most satisfactory methods for investigating legibility of print.’\(^\text{12}\) McLean found that:

> The findings of most ‘laboratory’ tests of legibility prove, if they prove anything, what suited those people, of that age and sex, at that time of day (tired? well fed? hungry? in good or bad temper?), in that month, in those conditions. But every job a typographer tackles is in a different set of conditions, and his skill is first to find out what those conditions are, and then to design particularly for them. The designer must always ask ‘what, why, who, when and where?’\(^\text{13}\)

Therefore, any new definition of readability and legibility to be relevant and accurate must take the human factor into account, and any new typefaces used with the new technology to be complete must also take account of the established ‘old theories’ and


‘rules’, like, for instance, the method of speed reading which was hailed by Tinker as ‘one of the most satisfactory methods for investigating legibility of print.\textsuperscript{14}

Chapter 4 entitled Analysis and Recommendations concludes the thesis with a summary of chapters 1, 2 and 3 before presenting a comparative analysis of current research into legibility, with particular emphasis on misreading or misrecognition of characters, and provides illustrations of the conclusions reached by way of bar chart and tables. One method used to judge the legibility of characters is to measure the misreading of individual characters by different methods such as short exposure as used by Sanford (1888), Tinker (1928) and van der Heijden (1984), distance method used by Phillips et al. (1983), blurring by diffusion used by Loomis (1982) and parafoveal vision used by Dockerary (1910). This chapter will demonstrate how comparative analyses of existing research into the misreading of characters will highlight what characters need redesigning and/or improving based on the misreading rates of characters, and this is done by way of charts and comparative analyses. The period between 1888 and 1984, for the purpose of the comparative analysis of the research, covers several changes in the reproduction of typography from the use of hot metal type in letterpress printing after the invention of punch-cutting machine in 1885. This machine was a typographical invention as fundamental as the mould of Gutenberg (c. 1440)\textsuperscript{15}, — phototypesetting or “cold type” in the 1950’s for offset printing and onto characters generated on a cathode ray tube with machinery, next computer aided typesetting such as Alphanumeric APS2 in 1963, IBM 2680 in 1967 and Linotron 202 in the 1978, — minicomputers-bases typesetting software introduced in the 1970s, and includes research not only into printed typography but also screen typography.

There is extensive research and study into typography, reading, writing, legibility and readability since the invention of writing and all to one purpose, i.e. to make type easier to read. The identifying of characters for the purpose of decoding them is a vital part of working this system i.e. reading and writing. Reading and writing ‘require schooling and practice, the deliberate shaping of the brain’.\textsuperscript{16} And yet after all the years of learning to use the system there is still a misreading of characters with all different kinds of type reproduction from hot metal to cold metal and digital type concluding that it is the shape of the characters – some more that others – is the causal factor for the misreading of characters. The chapter concludes by making recommendations for

\textsuperscript{14} Miles A.Tinker, \textit{Legibility of Print} (Ames, Iowa, U.S.A.: Iowa State University Press, 1963), 23.
\textsuperscript{16} Nicholas Carr, \textit{The Shallows} (London: Atlantic Books, 2010), 51.
further research into legibility. Among the recommendations for further research is that the complete findings in various research should be cross-referenced to get more accurate findings into which of the characters cause the most misreading.

Appendix One of the thesis contains a comprehensive list of the research into legibility and readability. Appendix Two contains the graphics of Benjamin Sherbow showing typography layout supportive of type spacing matters discussed in chapter 2. The thesis has an extensive bibliography of the works referred to throughout the thesis.
Chapter 1

Reading and Writing

Introduction
A historical overview of research into legibility and readability runs parallel with the history and development of the characters used for reading and writing, i.e. the characters of the alphabet. Bearing in mind that the thesis is about the economy of typography and a historical overview of research into legibility and readability, and as the history of the dual concepts of legibility and readability are inextricably linked to the history of reading and writing, it is appropriate that any discourse of the historical overview of research into the economy of typography should be commenced by first presenting an overview of the history of reading and writing. This is the main aim and purpose of chapter 1. ‘Why writing came into existence is a comprehensive question whose answer is shrouded in the mist of prehistory because, for, obvious reasons, there are no written records about what life was like prior to the invention of writing.’¹

Reading and writing involve a system of translating the sound in the spoken language to symbols and characters for the purposes of decoding them.

If reading and writing are one, as easily thought these days, if reading is writing, this oneness designates neither undifferentiated (con)fusion nor identity at perfect rest; the is that couples reading with writing must rip apart.²

Therefore, as reading and writing are considered as separate and distinct concepts each may be looked upon as separate and distinct issues.

The story and science of the reading brain
Reading and writing are not inherited in the way speech are, for instance, a child learns to talk without instruction by virtue of his or her innate talent. Reading and writing ‘require schooling and practice, the deliberate shaping of the brain’.³ Our minds have been trained to translate the symbolic characters that we perceive in spoken language. This form of translation of symbols into sounds or reading alters the way we think.

Steven Pinker in his publication How the Mind Works states: ‘The mind is a system of organs of computation, designed by natural selection to solve the kind of problems our

ancestors faced in their foraging way of life.\textsuperscript{4} Pinker argues that communication is part of human life and that training of the brain is vital to reading. The training of the mind along with the understanding of our environment and the use of symbols that represent the language we use when engaging with other people and the written word are some of the aspects that have altered and developed the mind. Neurological studies have shown that different languages demonstrate activity in different parts of the brain. Present day studies also reveal that the neural activity along brain pathways double or trebles when we look at meaningful symbols as opposed to meaningless scribbles.

Brain scans have also revealed that people whose written language uses logographic symbols, like the Chinese, develop a mental circuitry for reading that is considerably different from the circuitry found in people whose written language employs a phonetic alphabet.\textsuperscript{5}

\textbf{Figure 1:} Three Reading Brains. Source: Figure 3-1: Three Reading Brains. \textit{Proust and the Squid} by Maryanne Wolf. Chapter: “The Birth of an Alphabet and Socrates’ Protests” page 62.

\textsuperscript{5} Nicholas Carr, \textit{The Shallows} (London: Atlantic Books, 2010), 51.
The different systems of reading produce different ‘circuitry’ in the brain to understand the different systems of reading involving logographic symbols and a phonetic alphabet. Cognitive neuroscientist Wolf explains the way the brain learns to read. Reading builds pathways every time we read and recognise words which have different meanings like, for example, in Maryanne Wolf’s work *Proust and the Squid* the word ‘bug’ is given with different meanings, a six-legged insect, a Volkswagen and a glitch in software. Our experience and the context of the word give the word the intended meaning. The neuronal pathways for recognising letters and word patterns and the word become automatic due to retinotopic organisation (retinotopic organisation is the design feature in our visual system where soon after birth each neuron in the eye’s retina begins to correspond to a specific set of cells in the occipital lobes), and object recognition capacities and our ability to represent highly learned patterns of information in our specialised regions.\(^6\) The Chinese language, for instance, use a very particular set of neuronal connections while reading which differ significantly from the pathways used for reading English. No matter what system is used the end goal is the understanding of the arrangement or mode of operation to read and write.

Reading from a book links the brain with sight, sound and touch. In *Proust and the Squid*, referred to above, explains this link: ‘transforms mere marks on a page into meaning through a powerful blend of sight and sound. And lastly a book neatly links vision and touch, producing a perfect symmetry of distance and proximate discovery.’\(^7\)

It may be said here that reading from a computer has more of a split focus than reading from a book. The human attention is split with the extra information and the potential to access different web sites and web pages via hyper links that are linked to words, web sites and phrases. A present day distraction while reading a book could be that the book was made by handmade paper, but this is an exception rather than the rule of mechanical produced stock or various different stock used in the same book, such as the reproduction of high resolution halftone images on an art quality paper and the text matter on a lower grade of stock. Almost everyone has had the experience of moments of distraction when reading a book by a sudden almost unnoticeable encounter with a strange feeling of change by the disproportionate thickness of pages when turning. ‘In an age of virtual, mobile, split-focus distraction, the book is a link both to body and spirit.’\(^8\) It appears that the distractions of reading from computers is more profound than


\(^{7}\) Maggie Jackson, *Distracted: The Erosion of Attention and the Coming Dark Age* (New York: Prometheus Books, 2009), 182.

\(^{8}\) Ibid., p182.
that of the distraction of reading form a book. ‘To read a book is a grounding and an ascension all at one moment, a feat no computer can yet carry off.’

Reading and writing involve a system of translating the sound in the spoken language to symbols and characters for the purposes of decoding them, this is achieved by ‘schooling and practice’. Practice suggests what ‘we are what we read’ and ‘you read best what you read most’, and present day cognitive neuroscientists have discovered that the brain changes and developed with activity, reading is one such activity that generates activity and development in the brain. ‘The human brain was never evolved for reading… The only evolution was cultural — reading itself progressively evolved towards a form adapted to our brain circuits.’ The more access to books gave people greater opportunity to explore books and to learn how to read. This ‘evolution’ has resulted in the ‘brains of all adult readers are equipped with a finely tuned reading mechanism’. The ‘evolution’ of the reading brain and the availability of books in the Middle-Ages aided in the evolution of the reading brain and advance in literacy. The set of shapes (Latin or Roman alphabet) is simple enough to be stored in our ventral visual system and linked to our language. ‘Cultural evolution tuned our writing systems so well that it now takes them only a few years to invade the neuronal circuits of the beginning reader.’ By the age of four most humans have developed the ability to communicate through oral language. By the age of six or seven most humans can comprehend and also express their thoughts in writing. ‘These unique abilities of communicating through a native language clearly separate humans from all animals.’

After one year of education children usually match some spoken word, with written words and can write some letters and numbers. After about two years of education children usually begin to read familiar stories, sound out and decode unfamiliar words, and self correct when they make a mistake while reading aloud. After three years of education children usually begin to read aloud with proper emphasis and expression. Reading is now so fine-tuned that they can now read books, signage, packaging and anywhere text is found in the particular language that the child/reader understands and can read. History of reading and writing goes hand in hand with the schooling of

---

9 Maggie Jackson, Distracted: The Erosion of Attention and the Coming Dark Age (New York: Prometheus Books, 2009), 182.
13 Ibid., p303.
14 Ibid., p303.
children in reading and writing. With increased availability of book with the invention of printing lead to more of the public having access to book and the increase in schooling in reading and writing.

Each of the letters that we use in the Roman type contains elements that have been modified over thousand of years from the phonetic alphabets although ‘legibility has been neglected by the makers of phonetic alphabets in their desire to indicate phonetic similarity by similarity of form’ this lack of legibility adds another factor in learning to read. Some research estimates that Sumerian writing contained about nine hundred signs and over time was reduced to five hundred signs as syllabic writing increased. The first traces of a form of an alphabetical system date from 1700 BC and this is called Proto-Sinaitic, and this writing system borrowed the shapes of several Egyptian characters and used them to represent the Semitic language. ‘Signs no longer referred to meaning, but to speech sounds alone, and in fact solely to consonants.’ In the English language certain letters next to each other in a words can change its sound i.e. ‘ph’ and ‘f’ can both sound the same. Where there are a limited amount of characters involved, for instance, the 26 characters in the English alphabet reduces the amount of work to learn and operate the characters.

Figure 2: Sumerian writing: example of an early writing system represents some of the earliest texts found in the Sumerian cities of Uruk and Jamdat Nasr around 3300 BCE. Accessed: February 17, 2016. Available: http://www.ancientscripts.com/sumerian.html.

19 Ibid., p190
<table>
<thead>
<tr>
<th>Letter Name</th>
<th>Proto-Sinaitic</th>
<th>Early Phoenician</th>
<th>Greek</th>
<th>Phonetic Value</th>
<th>Letter Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>'aleph</td>
<td>יא</td>
<td>א</td>
<td>A</td>
<td>[']</td>
<td>ox</td>
</tr>
<tr>
<td>beth</td>
<td>ב</td>
<td>ב</td>
<td>B</td>
<td>[b]</td>
<td>house</td>
</tr>
<tr>
<td>gimmel</td>
<td>ג</td>
<td>ג</td>
<td>Γ</td>
<td>[g]</td>
<td>throwstick</td>
</tr>
<tr>
<td>daleth</td>
<td>ד</td>
<td>ד</td>
<td>Δ</td>
<td>[d]</td>
<td>door</td>
</tr>
<tr>
<td>he</td>
<td>ה</td>
<td>ה</td>
<td>E</td>
<td>[h]</td>
<td></td>
</tr>
<tr>
<td>waw</td>
<td>ו</td>
<td>ו</td>
<td>ꔚ</td>
<td>[w]</td>
<td>hook/peg</td>
</tr>
<tr>
<td>zayin</td>
<td>ז</td>
<td>Z</td>
<td>Z</td>
<td>[z]</td>
<td></td>
</tr>
<tr>
<td>heth</td>
<td>ח</td>
<td>ח</td>
<td>H</td>
<td>[h]</td>
<td>fence</td>
</tr>
<tr>
<td>teth</td>
<td>תש</td>
<td>ת</td>
<td>Θ</td>
<td>[t]</td>
<td></td>
</tr>
<tr>
<td>yodh</td>
<td>יד</td>
<td>יד</td>
<td>Ι</td>
<td>[y]</td>
<td>arm/hand</td>
</tr>
<tr>
<td>kaph</td>
<td>כ</td>
<td>כ</td>
<td>K</td>
<td>[k]</td>
<td>palm of hand</td>
</tr>
<tr>
<td>lamedh</td>
<td>הל</td>
<td>Λ</td>
<td>Λ</td>
<td>[l]</td>
<td>goad/crook</td>
</tr>
<tr>
<td>mem</td>
<td>מ</td>
<td>מ</td>
<td>M</td>
<td>[m]</td>
<td>water</td>
</tr>
<tr>
<td>nun</td>
<td>נ</td>
<td>נ</td>
<td>N</td>
<td>[n]</td>
<td>snake</td>
</tr>
<tr>
<td>samekh</td>
<td>ס</td>
<td>ס</td>
<td>Ν</td>
<td>[s]</td>
<td></td>
</tr>
<tr>
<td>'ayin</td>
<td>אי</td>
<td>א</td>
<td>Ο</td>
<td>[a']</td>
<td>eye</td>
</tr>
<tr>
<td>pe</td>
<td>פ</td>
<td>פ</td>
<td>Π</td>
<td>[p]</td>
<td></td>
</tr>
<tr>
<td>tsade</td>
<td>צ</td>
<td>צ</td>
<td>מ</td>
<td>[s]</td>
<td></td>
</tr>
<tr>
<td>qoph</td>
<td>ק</td>
<td>Q</td>
<td>Π</td>
<td>[q]</td>
<td></td>
</tr>
<tr>
<td>reš</td>
<td>ר</td>
<td>ר</td>
<td>Ρ</td>
<td>[r]</td>
<td>head</td>
</tr>
<tr>
<td>šin</td>
<td>ש</td>
<td>ש</td>
<td>Σ</td>
<td>[s]</td>
<td></td>
</tr>
<tr>
<td>taw</td>
<td>ת</td>
<td>T</td>
<td>T</td>
<td>[t]</td>
<td>mark (?)</td>
</tr>
</tbody>
</table>

Chinese scholars must learn several thousand signs. As recently as the 50’s, the rate of illiteracy in the adult Chinese population was close to 80 percent — before radical simplification and massive investment in education brought this figure down to about 10 percent.  

King Sejong of Korea in 1446 AD, for instance, moved away from the Chinese system of writing and introduced twenty-eight letters which were easier to learn and use, and called his system ‘Hangul’. Twenty-four of these characters are still in use today. Once writing norms are established, they attract emotional attachment, and hence discussions about the reform of a given orthography or script often resemble a religious was more than a rational discourse. The new alphabet introduced by King Sejong was used only for unscholarly and for practical purposes. The original Chinese characters were retained by Korean scholars, who were laboriously trained in the skill of writing and these were considered ‘serious’ writers. ‘Serious literature was elitist and wanted to be known as elitist.’ It was not until the twentieth century that this alphabet (Hangul) received widespread acceptance. The reduction in the amount of characters aided the ability to learn the written language easier.

Figure 4: ‘The Proper Sounds for the Instruction of the People,’ or the ‘Hunninjeongeum’, describes the new and innovative script for the Korean language as promulgated by King Sejong the Great in 1446 from National Hangul Museum opens to promote Korean alphabet. Accessed February 21, 2016. Available: http://www.korea.net/NewsFocus/Policies/view?articleId=122044#

The alphabet achieves its high level of efficiency through its economy of characters (mere-twentysix letters in many alphabets, compared with 900 Cuneiform characters and thousands of hieroglyphs). This reduces the number of symbols reduces the time and attention needed for rapid recognition; and thus fewer perceptual and memory resources are needed.24

The ability to read rapidly with fluent comprehension is achieved in the Roman alphabet by its limited number of characters consisting of twenty-six in total and by schooling. Yet typography and the twenty six characters of the alphabet can be presented in different styles and formats, for example, all uppercase/caps, uppercase and lowercase or handwritten, so the characters may not look the same in different positions, and is known as the invariance problem by psychologists. The different styles and formats contribute to the legibility and readability of characters which also affect the arrangement or mode of operation of typography in the economy of typography as a whole.

The invariance problem

Stanislas Dehaene outlines that perception is another matter that has to be taken into account when considering the question of reading. ‘We must identify words regardless of how they appear, whether in print or handwritten, in upper- or lowercase, and regardless of their size’25 this is known as an invariance problem by psychologists. An invariance problem involves words appearing in different positions, in different sizes, different typefaces, or even where words are handwritten. If the words always stayed in the same position and had the same appearance it would restrict the amount of the cells active and inactive on the retina: this ‘would suffice to decode a word, much like a black-and-white computer image is defined by the list of its pixels.’26 Reading is not just confined to identifying characters. In the case of the Roman alphabet comprised of 26 characters, reading is identifying ‘the thousand and one possible shapes that the actual characters can take on.’27 The shapes are the words, and words in different situations can have different meanings the process in reading are interactive some time additional information is needed to understand the text to give the true meaning to the words.

Maryanne Wolf gives the following example by saying: ‘The bow on the boat was covered by a huge red bow’28 meaning most people would need a second reading to get

26 Ibid., p18.
27 Ibid., p18.
the true meaning of the sentence where the first ‘bow’ and the second ‘bow’ have different meanings. This appears to reduce the number of symbols and further reduces the time and attention required for rapid recognition, and thus fewer perceptual and memory resources are needed and thus the opposite can be said: the more characters in a written language the harder it will be to learn and decipher. It may be gathered from this observation that modifications to reading systems have produced systems that translate the sound in the spoken language to symbols and characters for the purposes of decoding them.

The quick brown fox jumps over the lazy dog
THE QUICK BROWN FOX JUMPS OVER THE LAZY DOG
The quick brown fox jumps over the lazy dog
The quick brown fox jumps over the lazy dog

Figure 5: The invariance problem identifying the same characters in different forms, the above graphic shows the following text ‘the quick brown fox jumped over the lazy dog’ in different forms. From top bold upper and lower case, next all caps, the next two lines are in two different styles of script followed by same line hand written by two different people.

Scriptura continua

The original manuscripts and papyrus codex, for example, a papyrus codex of century vi AD: Avitus B. N. Lat 8913 (Lat. 2), see Figure 6 below had no word spaces nor did the scribes pay much attention to the order of the words: oral sound was the significant feature.


Books with no word spacing are now referred to as *scriptura continua* which means words run together without any breaks across every line on every page. This method reflected language’s origins in speech. ‘When we talk, we don’t insert pauses between
each word — long stretches of syllables flow unbroken from our lips’. The early scribes did not use word spacing, they simply transcribed speech. They wrote down the characters as they were uttered. Word spacing along with other ‘signs’ emerged on the medieval page ‘to provide supplementary information to guide the reader to the meaning of the text’, and thus allowed writing to be converted into the oral. ‘These “silent” paratextual signs did not form part of the text itself, the reader was expected to perceive them simultaneously with the text.’ In *scriptura continua* the reader’s eye moved slowly across the complete line, pausing frequently, and sometimes going back over the text to figure out where one word ended and the next began and what role each word played in the sentence. ‘Reading was like working out a puzzle… the slow, cognitively intensive parsing of text made the reading of books laborious.’ The codices, like the scrolls and tablets that preceded them, were almost always read aloud. Reading aloud aided in sounding out the words in *scriptura continua*, as sounding out of the syllables was crucial to deciphering the writing. It appears that the ongoing changes in writing from *scriptura continua* to text with words spacing and the ‘silent paratextual signs’ were a precursor to the way we read and write today.

Silent reading was not the norm with *scriptura continua*. Reading was performed orally to aid in deciphering the writing. Silent reading is the norm today involving the eyes scanning the page and ‘tongue held still’. Saint Augustine (13th November 354 – 28th August 430) gave a rather colourful description of the silent reading when referring to its use by St. Ambrose:

> When he read,” said Augustine, “his eyes scanned the page and his heart sought out the meaning, but his voice was silent and his tongue was still. Anyone could approach him freely and guests were not commonly announced, so that often, when we came to visit him, we found him reading like this in silence, for he never read aloud.

Although silent reading is the norm today, other factors and conventions have been added to typography to aid in the reading, thus moving away from *scriptura continua* style of writing and creating a new word order. Each change from the reducing the number of characters in an alphabet to adding spaces between works developed with the need to make type easier to operate. This is another aspect of the economy of typography.

---

32 Ibid., p71.
A new word order

By the start of the first millennium writers were beginning to impose conventions of word-order on their work ‘words in inscriptions were frequently separated by an ivy-leaf-like decoration design, forming a special, space-filling intraword character known as a *hederae*’\(^\text{35}\). These divisions between words *hederae* ‘which can themselves become distinctive decorative motifs. These *hederae* were placed not at the bottom of a line, as with our full stops, but were set halfway up the height of the letters.’\(^\text{36}\) However, the Celtic manuscript calligraphers were the first to leave a space between words so as to allow the reader to separate the string of letters into words more quickly, ‘Saenger

---


identifies the first properly spaced Latin manuscript as the Irish *Book of Mulling*, an illuminated translation of the Gospels dating from around 690 AD. In the early medieval period, the *scriptura continua* format of ancient manuscripts changed as space began to be introduced between words. By the thirteenth century *scriptura continua* was almost obsolete for text written in Latin and the vernacular. Punctuation marks were soon to follow. These changes moved text away from oral traditions leaving writing dependent upon the look of the groups of character as well as the sound. The word spacing reduced the amount of cognitivity used to work out the ‘puzzle’ of reading.

In the centuries before the invention of print produced books scribes produced copies of books and adapted their methods of work to changing needs.

Books needed by university faculties and the mendicant orders were supplied by a “putting-out” system. Copyists were no longer assembled in a single room, but worked on different portions of a given text, receiving payment from the stationer for each piece (the so-called pecia system). The ‘putting-out’ system by lay stationers began to replace monastic scribes and book production ‘had moved out of scriptoria three centuries before the advent of printing.’

It appears that workshops capable of turning out dozens of copies of the most popular books at a time, existed in many places in the early fifteenth century through this for the size of the population was a limited amount, this ‘made it possible for literate elite to develop a relatively sophisticated “bookish” culture’. There are no figures for the last fifty years of scribal culture to give an indication of the volume of books produced.

---

41 Ibid., p10.
42 Ibid., p8.
‘Indeed we have no figures at all.’\textsuperscript{43} The printed book ‘could be said to have arrived between 1500 and 1510’,\textsuperscript{44} with the first book printed around the 1450s, and this opened up the mass production of books. Little by little the printed book displaced the manuscript in library collections, and by the 1550, manuscripts were hardly used except by scholars for special purposes.\textsuperscript{45}

In Western Europe the language used in books in the fifteenth century showed that: 77 per cent of books were in Latin, 7 per cent were in Italian, 4-6 per cent were in German, 4-5 per cent in French and just over 1 per cent were in Flemish\textsuperscript{46}. The subjects covered in books at this time were as follows: religion 45 per cent, classical, medieval and contemporary literatures over 30 per cent, law 10 per cent and books on scientific subjects about 10 per cent.\textsuperscript{47} Along with the increase in production of books, printing also removed the possibility of corrupted text after being copied over the course of time, ‘all texts in manuscript were liable to get corrupted after being copied over the course of time.’\textsuperscript{48} The original books produced by scribes come from the spoken word, ‘heavy reliance was placed on oral transmission even by literate elites’ so that the books of the scribes was still linked to the oral tradition. The scribes work ‘produced a hybrid half-oral, half-literate culture’ where scriptoria and literary compositions were published by being read aloud and learning a book by relied on the spoken word.\textsuperscript{49}

\textbf{Characters and letters and how language works}

As stated reading and writing involve a system of translating the sound in the spoken language to symbols and characters for the purposes of decoding them. At the same time as the invention of writing people became more interested in the study of languages and their grammatical structures and compositions. Aristotle was the first to divide the sentence into two parts the subject and predicate, but he went no further than this. This division is still recognised today as an important tool in the analysis of a sentence. ‘First of all came what was called “grammar”. This discipline first instituted by the Greeks and continued mainly by the French, is based on logic.’\textsuperscript{50} Dionysius Thrax (170-90 BC) developed the steps of grammar or ‘parts of speech’ and produced the first complete book of Greek grammar. Thrax’s ‘parts of speech’, as he called them, fell into eight groups as follows: nouns, verbs, articles, pronouns, prepositions,

\begin{itemize}
\item \textsuperscript{43} Elizabeth L. Eisenstein, \textit{The Printing Revolution in Early Modern Europe}. 2nd edition (Cambridge University Press. 2005), 9.
\item \textsuperscript{44} Lucien Febvre and Henri-Jean Martin, \textit{The Coming of the Book} (London-New York: Verso. 1976), 262.
\item \textsuperscript{45} Ibid., p262.
\item \textsuperscript{46} Ibid., p249.
\item \textsuperscript{47} Ibid., p249.
\item \textsuperscript{49} Ibid., p8.
\item \textsuperscript{50} Ferdinand de Saussure, \textit{Course in General Linguistics} edited and annotated by Ron Harris (UK: Bloomsbury Academic, 1983), 1.
\end{itemize}
After the conquest of Greece in the mid-second century BC Roman scholars learned of the Greek works on grammar, and found that ‘grammer aims solely at providing rules which distinguish between correct and incorrect forms’⁵² and began to apply the same analysis to Latin. Priscian, a Roman grammarian, ‘teacher and writing in Constantinople in Byzantine times’⁵³ produced a grammar of Latin and is still used today in Latin textbooks. It was not till the fourteenth and fifteenth century that the rest of Europe began to look at their writing descriptions. Priscian’s account of Latin was imposed on Spanish, French, German, Italian and English languages despite the fact that they did not always share a Latin base. This was known as the Graeco-Roman grammar and is still taught in European schools down to the present day except in English speaking countries. In the seventeenth century a group of French scholars known as the Port-Royal Circle presented a universal grammar of French which largely broke free from the Priscianic tradition. In the nineteenth century European linguists began to realise that certain languages had systematic resemblances and so deducted that they came from a single common ancestor. Franz Bopp in his work published in 1816 entitled *The Sanskrit Conjugation System* ‘studied the connexions between Sanskrit, Germanic, Greek, Latin, etc.. though Bopp was not the first to observe these affinities or to consider that all languages belonged to the same family.’⁵⁴ This came after what Ferdinand de Saussure described as the second period of linguists and who found that ‘philology’ ‘is slavishly subservient to the written language, and so neglects the living language.’⁵⁵ This observation was not a new one as Plato also objected to this neglect of the living language in its relationship to reading and writing. However, as reading and writing become more available to people at large a greater link was definitely forged between the ‘living language’ and reading and writing.

The non-historical study of language structure started to come to the foremost towards the end of the nineteenth century. This study into language structure is now called general linguistics. The researchers at the start of general linguistics were Georg von der Gabelentz (1840-1893) from Germany, Jan Baudouin de Courtenay (1845-1929) and Mikolai Kruszewski (1851-1887) both from Poland. Ferdinand de Saussure (1857-1913) ‘holds pride of place as the first real essay into linguistic theory as we understand it now’⁵⁶. He said that: ‘A language is a repository of sound patterns, and

---

⁵⁵ Ibid., p2.
writing is their tangible form’. The prestige of writing is explained by Saussure in four points the last of which he speaks about the linguist: ‘Since the linguist’s voice often goes unheeded, the written form almost inevitably emerges victorious, because any solution bases on writing is an easier solution. In this way, writing assumes an authority to which it has no right.’ Saussure as a linguist himself held the spoken word as ‘an authority’ and not the written word, and that ‘the spoken word alone constitutes that object’ of study in linguistics. ‘A language and its written form constitute two separate systems of signs. The sole reason for the existence of the latter is to represent the former.’ Saussure takes the view that writing simply represents the spoken language in visual form. ‘Thus although writing is in itself not part of the internal system of the language, it is impossible to ignore this way in which the language is constantly represented.’ Saussure goes on to outline that we learn to speak before learning to write is forgotten, ‘and the natural relation between the two is reversed.’ The spoken word does not need the written word to exist but without the spoken word we would have no need for writing. A language is in a constant process of evolution but writing seems to remain fixed.

Whether natural or not, the faculty of articulation words is put to use only by means of the linguistic instrument created and provided by society. Therefore it is no absurdity to say that it is linguistic structure which gives language what unity it has.

The structure of language is thus ‘created and provided by society’, and the written form only translated this important trait that humans have to speak ‘forces operating permanently and universally in all languages’ are what are visualised in the written language. ‘Speech sounds are only the instrument of thought, and have no independent existence.’ The object of a science of language is not its written forms but its oral existence and evolution. Language is related to a broader mental facility whose function is to deal with signs, whether visual or vocal. Saussure having oral speech as primary, and having writing as the basic form of language, thought that natural language was a puzzle. Paul Bouissac quotes Saussure as follows: ‘a phenomenon that appears to him as both stable and instable, both arbitrary and necessary, both rational and irrational.

58 Ibid., p29-30.
60 Ibid., p28.
61 Ibid., p44.
62 Ibid., p29.
64 Ibid., p21.
depending on the point of view from which it is approached.\textsuperscript{65} What is Language? Wittgenstein claims that language gives us a picture of the world\textsuperscript{66}, and type characters are pictures of languages, and clarity of picture gives us clarity of the world. Legibility of characters can following on from this point giving us clarity of the world we live in and clarity in speech. Speech is dependent on language and writing is a visual form of speech. Speech expresses the verbal sounds that construct a language. Steven Pinker in his book, \textit{How the Mind Works} points out that:

\begin{quote}
The species’ best minds have flung themselves at the puzzles for millennia but have made no progress in solving them. Another is that they have a different character from even the most challenging problems of science. Problems such as how a child learns language\textsuperscript{67}
\end{quote}

Writing by converting the oral language into written symbols, the alphabet. The alphabet has a limited number of characters and have a start and a finish and so could be modified, but this is not the same for a language as there is no obvious place to start or finish. Language is dependent on human organs such as the voice box, vocal cords and brain, and is picked up from the social environment from fellow speakers and the people we interact with. It is inherited depending on where we are and the society we live in. A spoken word has an aspect we can hear (picture in our minds eye) and a written word is an aspect we can see, this is what Saussure called a ‘signified’ and ‘signifier’. A ‘signified’ is a concept or meaning associated with that sensory perception.

\begin{quote}
‘A text remains, moreover, forever imperceptible’\textsuperscript{68} but the invention of writing has led to contradictory views on which is more important the oral or the written word. The written word came to serve archival functions which in some cases surpassed the authority given to traditional oral functions. Eisenstein cited in Olson said ‘new devices served existing functions on such a dramatic scale that they in effect change those functions’.\textsuperscript{69} ‘At least since Aristotle’s time it has been assumed that writing is a graphic device for transcribing speech’\textsuperscript{70} or as Aristotle in \textit{De interpretatione} said ‘written words are the signs of words spoken’\textsuperscript{71}. The letters were seen as the verbal form of the text during the Middle Ages ‘-- one version of what it says versus what it means,’\textsuperscript{72} in other words there was a great deal of ‘reading between the lines’. In the thirteenth

\textsuperscript{68} Jacques Derrida, \textit{Dissemination}. Translated by Barbara Johnson. (University of Chicago: Continuum International Publishing Group, 1981), 69.
\textsuperscript{69} David R. Olson, \textit{The World on Paper} (Great Britain: Cambridge University Press, 1994), 61.
\textsuperscript{70} \textit{Ibid.}, p65.
\textsuperscript{71} \textit{Ibid.}, p65.
\textsuperscript{72} \textit{Ibid.}, p146.
century the humanists began to develop notions of a more literal understanding. The history of reading in the West is largely the history of reading the Christian Bible even if, as we shall see, that tradition was deeply influenced by classical Greek, Arabic and Jewish traditions. The preference of the spiritual interpretation at the expense of the literal was starting to cause disputes about the meaning of texts. The early Christian tradition, largely as a reaction against the Jewish concern with the “letter of the law” and strict ritual observance, countered that “the letter killeth but the spirit giveth life” (II Cor. 3:5). In the twelfth century at the Abbey of St. Victor in Paris the significance of the need to have a literal meaning of scripture was identified, and a scholarly approach was taken thereafter to the whole issue of interpretation. It may be said that words were no longer ‘written words are the signs of words spoken’ but they can be interpretations and ‘giveth life’ of their own. The presentation of these symbols as representing the spoken word has changed from clay tablets and papyrus, to vellum and paper and now to representation on screen. Not only did the material on which the symbols appeared change, but also the way in which the typography was presented on these materials changed, i.e. from clay tablets to rolls of papyrus, and then the codex.

**Codex a change in the way books were produced**

The greatest benefactors of mankind are unsung and unknown — the inventor of the wheel, the deviser of the alphabet. Among their number we should place the invention of the codex. The ‘codex’ is a form of book which has sheets superimposed on each other, folded across the middle and then secured by stitching so that the sheets open into pages. The codex is not glued or sewn together to form a long roll. The usual form of book in late antiquity and in the middle ages was the codex. As early as the second century AD, Egyptian Christians were imitating the papyrus codex, which allowed a more economical use of the writing material than the roll, as both sides of the material were used. Books have changed and developed since the invention of the vessel for typography and reading and have changed primarily to give the readers what they demand.

---

74 Ibid., p.145-146.
78 Ibid., p.20.
As stated ‘the history of reading in the West is largely the history of reading the Christian Bible.’ The way of reading was greatly influenced by the practices of translation of sacred texts.’ The Bible was first translated into Latin by St. Jerome. He wrote that there was no loss of meaning if a word or two were added to the text. So it is not surprising that the first book printed by Gutenberg was the Bible. In the late fifteenth century the printer’s workshop started to take over the reproduction of written

---

80 Ibid., p146.
material from the copyist’s desk. ‘This shift, which revolutionized all forms of learning, was particularly important for historical scholarship.’

Paper, as the primary material, was a major factor in the spread of printing with movable type. Gutenberg’s first invention was movable type; his second, was the printing press; his third was oil based ink which worked with the metal characters. Water based ink did not work well with metal characters. ‘Oil varnishes were known to European painting circles before Gutenberg’ and his knowledge of these oil varnishes formed the basis for his own oil based ink. The ingredients of Gutenberg’s ink are not known and have not been identified, but it is believed to be similar to other printing inks of the period. ‘The superb quality of his printed matter, there can be no doubt that he was meticulously careful in the production of his varnish and black’ and that only the best ingredients would have been used and amongst these would have been the best oil, and at that time the best was nut oil, and not linseed. The oil would have been old nut oil and this would have been cooked to give it its drying properties. The recipe of De Ketham No. 6 is the earliest recorded ink formula from the late fifteenth century. ‘By the time of Gutenberg’s youth paper was plentiful and sold for approximately one sixth the price of parchment.’ The availability and cost of paper was a contributing factor to the availability of printed books.

It seems here that the invention of paper along with ink and movable metal character was a giant step in presenting writing to the reading public, and of presenting the system of translating the sound in the spoken language to symbols, in larger, faster quantities than with manuscripts. ‘The fact remains that the initial increase in output did strike contemporary observers as sufficiently remarkable to suggest supernatural intervention.’ The production of manuscripts or handwork continued in the fifteenth century and a large number of manuscripts produced during this time were copied from early printed books. ‘Thus handwork and presswork continued to appear almost indistinguishable, even after the printer had begun to depart from scribal conventions’.

**Spread of reading and growth of literacy**

The availability of books contributed to the growth of literacy. In the nineteenth and twentieth century the reading public became larger and larger due mainly to the printing

---

83 Ibid., p86.
87 Ibid., p23.
trade’s offer of more and cheaper reading material, and greater facility for obtaining books by loan, purchase or subscription. General education in Britain (it will be remembered that Ireland was part of the United Kingdom at that time) can be traced by the following dates:

1785: London Society for Promoting Sunday Schools;
1803: Sunday School Union;
1833: First public grant for educational purposes;
1867: Beginning of the University Extension Movement;
1869: First College for women (Girton, Cambridge);
1870: Compulsory school attendance;
1890: Free elementary education established.

Compulsory and free education on the elementary school level was achieved, at least on paper, in most civilized countries in the course of the nineteenth century. 88

Reading is a skill that one has to learn, that is, to be able to identify characters and groups of characters. The thesis question is concerned only with the Roman alphabet, and not with the other alphabets of which there are many, for example, Arabic and Chinese.

As already stated, writing and reading involve a system of translating the sound in the spoken language to symbols and characters for the purposes of decoding them.

‘Writing and print and the computer are all ways of technologizing the word.’ 89

Advances in technology have introduced digital reading in computers, iPads, ebooks, Kindle and smart phones which are now used for reading, surfing the web as well as other activities such as watching films and communication. ‘The first information-processing machine that the Net replicated was Gutenberg’s press.’ 90 Thus, it can be seen, that handwritten text moved to printed text and then to text on computers, the ongoing changes in the story of writing. The ‘invariance problem’ remains the same, decoding the symbols of the spoken word in different formats and styles all with one end goal to decode the written symbols.

**Objection to the technology of writing**

Plato’s objections to writing in the *Phaedrus* were essentially the objections against a new technology, i.e. the technology of writing.

‘Plato, however, condemned writing, that is, this exteriorisation of attention. …the poisonous characters of writing as remedy — that is, as pharmakon — of which the side effects here appear to be much worse than the ill that is the finitude of

---

memory does not mean that Plato condemns outright the practice of writing or of reading. He himself writes ceaselessly.'

Similar objections may be made when it came to computers. Plato’s first objection to writing was that it was inhuman, that it was a manufactured object, and the same may be said about computers. The second objection was that writing destroys memory, when something is written down there is little or no need to remember it, i.e. those who write will rely on external resources, and the same can be said about calculators and computers, by relying on equipment to calculate and record. Plato’s third objection to writing was that written text was not responsive, and the same may be said for computers if you require an explanation in text, i.e. you get more text and this might not clarify matter. The next objection that Plato had against writing was that the written word could not define itself as well as the natural spoken word; real speak exists between people and there is a mix of give and take regarding information; the written word stays as it is, just like computers. Oral speech is natural to human beings, every human being in every culture learns to speak, that is, unless he or she is physiologically impaired. Writing is a technology or a system of translating the sound in the spoken language to symbols and as Walter Ong states: ‘Technologies are not mere exterior aids but also interior transformations of consciousness, and never more than when they affect the word.’

Mrs. Beatrice Warde in an address to the British Typographer’s Guild in 1932 spoke about words, sound and characters with the following:

There is no “explanation” whatever of the fact that I can make arbitrary sounds which will lead a total stranger to think my own thought. It is sheer magic that I should be able to hold a one-sided conversation by means of black marks on paper with an unknown person half-way across the world. Talking, broadcasting, writing and printing are all quite literally forms of thought transference.

The written word is an artificial aid to the human potential, it helps us to partake and also to observe from a distance, to be objective and to take an active part.

We have not become aware of the possibility of arranging the entire human environment as a work of art, as a teaching machine designed to maximize perception and to make everyday learning a process of discovery… Printing technology created the public. Electric technology created the mass.

---

The media of the Net

The media of the Net has taken in all sorts of communications and presented them in its own format. The Net with its inclusion of text, pictures and sound has engulfed the major communications of print, sound and image and recreated the traditional medium in its own style and image. The existing media for communication still exist and co-exist with the new technology the same as in the fifteenth century where manuscripts co-existed with incunabula. One of the major differences between the fifteenth century and the present time is that the new technology of print ‘imitated late medieval manuscripts’ this imitation used the basic shape, letter form and material. The computer adapted text and images to its own format and cannot be mistaken for a book, unlike the early printed books, ‘so much looked like a contemporary manuscript, that it was sometimes mistaken for one, not only by the 15th-century purchasers, but even by later librarians.’ The same cannot be said about the relationship between the printed book and the computer which has no resemblance at all to a book.

‘A change is upon us—nothing can be clearer. The printed word is part of a vestigial order that we are moving away from—by choice and by societal compulsion.’ The internet also took the existing text, images and sound and ‘injected the medium’s content with hyperlinks, breaks up the content into searchable chunks, and surrounds the content with the content of all the other media it has absorbed.’ These new changes have also changed the way we absorb and comprehend information. Working through a page on screen involves scrolling and clicking which requires different physical actions than holding a book and turning pages. The tactile quality of the paper is also removed when reading from a screen. The method of reading on screen and navigating on screen influence the degree of attention and the amount of concentration given to the article.

People were becoming accustomed to the way the Net managed and presented text and information ‘as people’s minds became attuned to the crazy quilt of Web content, media companies have to adapt to the audience’s new expectations.’ As soon as an electronic book has links and connections to the Web the book is changed and also the way it is received and the experience of the reader also changes. An ebook is a different entity from a printed book. All-purpose search engines such as Google, Bing search

97 Ibid., p23.
98 Seven Birkerts, The Gutenberg Elegies: The Fate of Reading in an Electronic Age (United States: Ballantine Books, 1994), 118.
100 Ibid., p94.
from Microsoft, Yahoo!, AltaVista and Cuil and other search engines are perfecting their searches not only for text, but also for video and audio content, and all of these are linked into the ebooks. These search engines are so refined that they draw our attention away from the page of text to extra bits of related information in a way not giving the reader the full picture but linking to snippets. This results in the breaking of attention as Nicholas Carr put it: ‘We don’t see the forest when we search the Web. We don’t even see the trees. We see twigs and leaves.’

We only see part of the full picture. Because of the brain’s plasticity the actions required to alter our brains quickly and as thoroughly as possible are the same actions used when working on the Web. ‘It’s that the Net delivers precisely the kind of sensory and cognitive stimuli—repetitive, intensive, interactive, addictive—that have been shown to result in strong and rapid alterations in brain circuits and functions.’ Working, reading and exploring the Web is changing the way we process information, and also the outcome we get from reading on a computer with links and searches available at our fingertips.

The look and presentation of text layout between reading on paper and reading on computer has changed with the invention of computers and their availability to the reading public. In simple terms the change is between paper and screen. Reading a book has the unique tactile qualities of paper; reading on computer has the advantage of ease of storage and retrieval of information. Research into the differences between reading on paper and reading on screen highlighting the difference in speed of reading between the two.

By far the most common experimental finding is that silent reading from screen is significantly slower than reading from paper (Kak, 1981; Muter et al, 1982; Wright and Lickorish, 1983; Gould and Grischkowsky, 1984; Smeshhammar et al, 1989). Figures vary according to means of calculation and experimental design but the evidence suggests a performance deficit of between 20% and 30% when reading from screen.

Andrew Dillon (1992) goes on to say in his paper ‘Reading from paper versus screens: a critical review of the empirical literature’ published in the Ergonomics, 35(10), 1297-1326, that outcome measures concentrate on what the reader gets from the text in the context of information retrieved, accuracy of recall and time taken to read the text. Process measures are more concerned with how the reader uses a text, eye movement and eye fatigue. The advances in technology and the improvement of screen and software in the 2000s rendered the research done in the 1970s and 1980s out of date.

102 Ibid., p116.
Reading, and the representation of the spoken word, have produced what is known as the ‘standard’ of arrangement and position of words, and the standard of writing ‘we talk about one variety of a language being the ‘standard,’ with the implication that any other version isn’t as good’. The ‘standard’ of English in use today has developed and evolved over years of use and style of speech. In the beginning the scribes transcribed the sounds they heard without word spacing as in *scriptura continua* and later the Celts added word spacing to aid reading and the deciphering of the written text. Short hand and reducing words to the basic elements have been in existence for several centuries and a very long time before present day texting and computer speak. These agreed principles of speech and writing give us an understanding of our language and the way we communicate.

Agreed-upon interpretations of words or phrases make it possible for people to use language (rather than, say, charades or brute force) to get their meaning across. If I say “chocolate mousse” when I mean “strawberry shortcake,” it’s no surprise when I fail to get the dessert of my choice.

The way we communicate with writing and text has changed over time but some trends stay the same. First came the refining down of the characters of the alphabet to twenty six, next came the division between words, marked by dots, triangular incisions or by ivy-leaf designs (*hederae*) then on to adding of word spaces and punctitation marks and also hyphenation and abbreviation of words. ‘The world of IT, computerised editions of books, and scanned images does indeed offer its own separate and beguiling culture.’ Each new technology does not replace the previous one, ‘rather it augments it, and offers alternatives’. With the invention of printing books with movable type the scribes believed that their method of producing book was superior to the new printed version, ‘the Benedictine monk Johannes Trithemius believed that scribes should not cease their work, since only by writing could work be preserved’. As with text on mobile phones, tablets and computers text is presented in an alternative form but keeps its original aspects, character shapes, word spacing (in some places), punctuation and abbreviation of words. As Naomi Baron states ‘there’s a international perception that computers and mobile phones are affecting everyday language, and that these effects are generally not for the better.’

105 *ibid.*, p167.
108 *ibid.*, p20.
109 *ibid.*, p20.
short hand such as \textit{U} for \textit{you} or \textit{B4} for \textit{before} existed long before texting came into vogue with mobile phones and computers. An example of this is ‘if this were the year 1750 and I, a gentleman, were writing to a friend, I might well close the letter with the words “Yr Hm Ser,” that is, “Your Humble Servant.”’\textsuperscript{111} Thus offering ‘alternatives’ to the full word but staying true to the sound in the spoken language.

Back even further during the time of the Roman Empire ‘Tiros the secretary of Marcus Tullius Cicero, had the idea earlier, when he used the letter “c” as shorthand for Latin cum (meaning ‘with’). In the same vein, abbreviations such as \textit{U} for \textit{you}, \textit{R} for \textit{are}, \textit{4} for \textit{four}, and obviously \textit{yr} for \textit{your} were around for decades before they began infiltrating American text messages.’\textsuperscript{112}

The style of writing reflects the everyday spoken word for the generation that is involved in texting and writing both online and offline and ‘contemporary writing is increasingly informal. Part of that informality comes from the growing trend for writing (both online and off) to approximate informal spoken language.’\textsuperscript{113} The invention of modern methods of communication has exposed the extensive use of abbreviations and informal writing. ‘Computers are not the cause of contemporary language attitudes and practices but, like signal boosters, they magnify ongoing trends’.\textsuperscript{114} Language does not develop and change with new technology, but the user of the new technology adapts the words for his or her own needs in the new format thus including abbreviated words into basic sounds and shorthand as part of informal text, and as a result these abbreviated word and shorthand become commonplace. Writing has not changed, keeping the same characters or alphabet and basic word form, using the same system of translating the sound in the spoken language to symbols and characters for the purposes of decoding, but these symbols have been adopted by the users to aid in the legibility of the text, to make the characters fit for use (in some cases with a restricted space) without altering the sound, and as a result the systems of characters are adopted for the new format, i.e. ‘Yr Hm Ser’ in 1750s to present day texting ‘C U later’. Abbreviated words do not change the words they are just altered for use.

An additional force behind this informality is a redefinition of what is ephemeral and what is durable about linguistic expression. Recording devices aside spoken language is inherently evanescent. Once we have uttered a sentence—grammatical or otherwise—it’s gone. Part of the genius of human conversation is that we commonly ignore (or at least forgive) one another’s mispronunciation or slips in grammaticality.\textsuperscript{115}

\textsuperscript{111} Naomi S. Baron, \textit{Always On: Language in an Online and Mobile World} (Oxford New York: Oxford University Press, 2008), 176.
\textsuperscript{112} \textit{Ibid.}, p176.
\textsuperscript{113} \textit{Ibid.}, p165.
\textsuperscript{114} \textit{Ibid.}, p171.
\textsuperscript{115} \textit{Ibid.}, p166.
The later use of notebooks to record personal ideas developed from the use of commonplace books.

A book in which commonplaces or passages important for reference were collected, usually under general heads; hence, a book in which one records passages or matter to be especially remembered or referred to, with or without arrangement.¹¹⁶

Notebooks were ‘commonplace’ for recording notes before the use of computers for recording notes and looking up references. Referring to a book as commonplace in the present moment of time has a completely different meaning because the English language and its use have changed the meaning of commonplace unremarkable and which is in direct contrast to the historical meaning of ‘a passage of general application, such as may serve as the basis of an argument; a leading text cited in an argument.’¹¹⁷ ’Writing will increasingly become an instrument for recording informal speech rather than the distinct form of linguistic representation that emerged by the end of the seventeenth century in England.’¹¹⁸ Commonplace-books were used for references and recording interesting facts, quotes and thoughts to be accessed and used to back up facts both in written and verbal form up to the seventeenth century. These forms of reference are no longer in use and have been replaced by Google searches and other electronic forms of searches. The changes in technology have altered the ways we read and look up reference materials: from a commonplace-book to Google search, it is now ‘commonplace’ to search electronically and read from screen.

It appears that with the invention of the internet and the use of URLs have brought back groups of words without word spacing that look like scriptura continua, i.e. www.irishtimes.com, www.pensionsombudsman.ie and www.tsogosunhotels.com The lack of word spacing demonstrates a moving back to the original transcribing of the oral language. The evolution of language and reading go hand in hand but the difference is that language is instinctive and reading has to be taught.

For a writing culture to emerge, a sizable number of its members need ways of creating, disseminating, and deciphering the written word. People must have access to the tools of production (be them personal computer or quills on parchment) and knowledge of how to use them.¹¹⁹

Once the writing culture has been developed the reading follows, the writing is intended to be read and if it cannot be read it fails to fulfil its function. The change in the requirement of presentation from paper to screen must also be taken into account.

¹¹⁸ Naomi S. Baron, Always On: Language in an Online and Mobile World (Oxford New York: Oxford University Press, 2008), 171
¹¹⁹ Ibid., p186.
The visual forms of the oral sound have to be satisfied to work with the new technology. The characters need exploration to see what is required for the comprehension of the human brain that has been altered with the introduction of the new environment and use of the computer.

That a unique human language instinct seems to be incompatible with the modern Darwinian theory of evolution, in which complex biological systems arise by the gradual accumulation over generations of random genetic mutations that enhance reproductive success.\textsuperscript{120}

Writing is not like the language instinct, it works by using words, which can be represented both on screen and paper (on and off the computer). Plato describes logos in his book \textit{Phaedrus} as more the son than the father of speech. \textit{Logoi} is the ancient Greek for ‘words’, or ‘things said’.\textsuperscript{121} With text moving into the realm of computers it can be said that ‘Plato’s son’ is moving away from their centuries old home of paper and physical books, and moving into the new home of computers. Computer language has changes the symbols for reading that of the alphabet into glyphs and characters where a glyph is the image of a symbol used in a writing system or a notational system, and a character is the simple description, primarily linguistic or logical, or an equivalence class of glyphs. The relationship between signifier and signified in linguistics can be compared to the relationship between characters and glyphs where the meaning of the glyph is the character. Ferdinand de Saussure is credited for saying in his work \textit{Course in General Linguistics} ‘Whether I write in black and white, in incised characters or in relief, with a pen or a chisel—none of that is of any importance for the meaning.’\textsuperscript{122} No matter what format the words take what is important is the meaning of the words and give the readers what they demand, i.e. text that is legible and readable.

\textbf{Conclusion}

The development of reading depends on the legibility of the typography and characters ‘recognizing patterns, planning strategy, and feeling’, in other words, reading and writing are interdependent, and also depend in some part on the construction of the characters and their relationship to each other.

As Joseph Epstein put it: ‘A biography of any literary person ought to deal at length with what he reads and when, for in some sense, \textit{we are what we read.}\textsuperscript{123} Zuzana Licko, publisher of \textit{Emigre} magazine founded in 1984 stated that ‘you read best what

\textsuperscript{122} Yannis Haralambous, \textit{Fonts & Encoding}. Translated by P. Scott Horne. (United States of America: O’Reilly Media, Inc., 2007), 54-55.
you read most, and this goes for the context of the typography as well as the shape of the characters. Reading is without doubt a habit formed by using and repeating the reading action, and by schooling and training. The shapes of the characters in the Roman alphabet have changed little since the inception of characters but what has changed is the way we read, and reading methods and habits have had a direct affect on the legibility and readability of characters.

Readable writing is desirable and important for the reader’s sake. If writing is not readable by the intended reader it does not fulfil its purpose. The reader must be the judge. As already stated many times you read best what you read most, and it is the same for typefaces as for the method of reading used, be they printed or electronic typography. Since the inception of communication with symbols and characters the need to make these characters legible and readable developed along with the use of the characters, yet legibility is an abstract concept which is based on what the reader thinks based on the text that is presented.

Reading and writing have developed over time with one purpose, and that is producing a system of translating sound in the spoken language to symbols and characters for the purposes of decoding them. There have been many alterations down through the centuries to the system in use today, but one of the constant features is that writing must be understood, readable and legible. Legibility and readability would not exist without the written word, and that involves understanding and decoding the system that represents the spoken language in symbols. Legibility and readability are concepts that are inextricably linked to reading and writing refined by the traditional assumptions of typographers, and defined by scientific research though not in a completely satisfactory way. ‘The readability has to do with how easy, difficult, interesting, or accessible its contents are, relative to the reader. When typography and other physical aspects are concerned, one speaks of legibility.’ In other words, legibility is concerned with the visual perception of typeface and layout. The typographic practitioner presents the reading public with the raw material and the finished product for reading. ‘You read best what you read most’.

---

Chapter 2

Legibility and Readability

Introduction

This chapter will discuss the two fundamental factors at work in the economy of typography, viz. the practical presentation of typography for legibility and readability. Chapter 1 dealt with writing and reading and it was shown that it involved a system of translating sound in the spoken language into symbols and characters for the purposes of decoding them, and also that an understanding of these symbols required schooling and practice. This schooling and practice depended on the legibility of the typography and characters ‘recognizing patterns, planning strategy, and feeling’,¹ and all these factors depended in some part on the construction of the characters and their relationship to each other alone, or in pairs, or in groups of characters. Readability has to do with how the eye can absorb the message and move along the line of text and/or the style of language used. ‘The readability has to do with how easy, difficult, interesting, or accessible its contents are, relative to the reader. When typography and other physical aspects are concerned, one speaks of legibility.’²

Legibility, is concerned with perceiving letters and words, and with the reading of continuous textual material. The shape of letters must be discriminated, the characteristic word forms perceived, and the continuous text read accurately, rapidly, easily, and with understanding…[.]Optimal legibility of print, therefore, is achieved by a typographical arrangement in which shapes of letters and other symbols, characteristic word form, and all other typographical factors such as type size, line width, leading etc., are coordinated to produce comfortable vision and ease and rapid reading and comprehension.³

In other words, legibility is concerned with the visual perception of typeface and layout⁴. Legibility is therefore an abstract concept that is affected by layout and design of type, layout and design of type can aid in legibility by assisting the eye to identify and thus decode the symbols of translating sounds in the spoken language to symbols. Readability also involves decoding the symbols that represent the spoken language, and the level of education and knowledge of a subject along with recognition of words: if the reader has a good knowledge on the subject of the text, the text will be more

readable to the reader. Having a familiarity with words and the subject of the text aid in the readability of a text. The subject of text in relation to legibility and readability will be looked at in this chapter by reference to the works of leading typographic designers such as Frederic W. Goudy, Hermann Zapf and Stanley Morison and others. An extensive list of research in legibility and readability is also to be found in Appendix One of the thesis. Their research will show that the concepts of legibility and readability, notwithstanding their differences of purpose, are both interdependent and interrelated.

Several works and experience related assumptions on what makes typography legible and readable grew out of traditional practices by typographers since *circa* 1450, and these include leading, line length, different style typefaces for different types of jobs (i.e. swash letters, script, serif and sans serif) and position on page (i.e. page margins and gutters). The contribution of these assumptions to the evolving concepts of legibility and readability through the ages will be considered in this chapter. These assumptions on legibility and readability for continuous type relate to size of type, length of lines, colour and the space between characters and between lines of text amongst other design features, give the reading public typographical material they can read and want to read. These aspects are incorporated into the design and layout of typography to improve the clarity of the text, and thus make the type easier to identify and decode i.e. a ‘easy-read’.

The economy of typography and a historical overview of research into legibility and readability run parallel with the history and development of the characters used for reading and writing, i.e. the characters of the alphabet. Chapter 1 reviewed the history of reading and writing, and now chapter 2 will discuss and conduct an analysis into the dual concepts of legibility and readability, and also, it will consider the work and experience related assumptions and traditional practice on what makes typography legible and readable.

**Legibility from a practical basis**

The information about legibility and readability comes from two main sources. One: from a practical application and a working knowledge that have developed since the start of printing and typography. Two: the theoretical and analytical research carried out in laboratories under controlled scientific conditions. Appendix One of the thesis gives a comprehensive list of the research into legibility and readability. The knowledge from working with ‘type’ and ‘roman type’ comes from typographers and individuals whose
career is typography, and is assumed to aid in the legibility and readability of text through a combination of several features i.e. character design, leading, word and character spacing and line length, and is not dependent on one factor only. The ‘scientific research’ comes from psychologists such as Albert Tinker and James McKeen Cattell, and ophthalmologist research of Louis-Émile Javal and is covered mainly in Chapter 3: Criteria and Methods used in Typographical Readability and Legibility Research. The ‘scientific research’ used commercial type as its source material the characters of which are designed mainly by typographers who apply the working knowledge developed and accumulated since the start of print and typography.

**Roman type**

Any discussion of the economy of typography must necessarily refer to the Roman alphabet and the history of Roman type. The practical presentation of typography depends not only on the layout of typography but also on the characters that have been designed. As already stated, typographers apply the working knowledge developed and accumulated since the start of print and typography. The tools for reading and writing for the purpose of this chapter will be roman type and the English language. The first roman type was based on a ‘formal book hand’ that was perfected in Italy by humanistic scribes during the first half of the fifteenth century. It was first used chiefly for editions of classical authors.

…by the end of the fifteenth century, Italy had provided the rest of Europe with the three principal type of letter form that we are still using in printing today: the monumental capitals founded in inscriptions, the *roman tondo* characters and italics, introduced into typography by Aldus Manutius in 1510.5 This type is still used in printing today. The Roman type has a long history with its roots in the earlier forms of type in Italy for public and private use or reading.

Roman type was derived from earlier forms of typography used by civilisations around the Mediterranean region. Amongst the earlier records of typography specifically for the public use were the Twelve Tables. The Twelve Tables set down early Roman law in large bronze tables which unfortunately have since disappeared, however subsequent documents give an idea of the impressive series of seven large bronze tablets dating back to the second and first century BC. ‘The two most recent of these are in the Latin script and these contain religious percepts, laying down the ritual

---

5 Armando Petrucci, ‘Forms and History of Writing in Italy’ *A History of Writing, from hieroglyph to multimedia*, edited by Anne-Marie Christin (France: Flammarion, 2002), 311.
order for ceremonies held in the city.” The Twelve Tables informed the citizens of laws and rituals that were vital elements of Roman life and, accordingly, had to be presented in a way that left no room for misunderstanding. As ignorance of the laws was no excuse or defence the text had to be clear in layout and character design so the characters could be decoded and understood clearly by the reader. As stated ‘readability has to do with how easy, difficult, interesting, or accessible its contents are, relative to the reader. When typography and other physical aspects are concerned, one speaks of legibility.’ Legibility and readability were vitally important components when making the Tables and in relation to the information conveyed by them. These Tables were made to inform the whole of Roman society, and not just the elite, and had to be clear and easy to understand and read. The success of the legibility of these typefaces (used in the Twelve Tables) led this form of character to be used again and again in different formats: ‘the superior legibility of roman encouraged its use in all sorts of book’, as stated the text was designed to be clear and easy to read/decode, or to put it another way it was designed to be legible and readable. In Italy a few vernacular books were set in roman type from the beginning. The legibility of roman type aided in its spread outside of Italy and ‘books in English began to be set in roman from the late 1550s’. During the eighteenth century the design of the roman types underwent a radical change resulting in the style known as ‘modern style’, and such typographical style was used in the nineteenth century, and is still the typographical style used today in newspapers and many books.

The difference between type, roman type, alphabet, letters and words

The following terms describe different aspects of the symbol used to represent the sounds in the spoken language: ‘type’, ‘roman type’, ‘alphabet’, ‘letters’ and ‘word’. A preliminary analysis of the actual physical representation of ‘type’, ‘roman type’, ‘alphabet’, ‘letters’ and ‘word’, is required to set the scene for legibility and readability. When we say roman type we refer to the characters or symbols we use today, i.e. the twenty-six characters found in the English alphabet. Two experts of note in the field of typography: Stanley Morison, (1889 – 1967), an English typographer, designer and historian of printing, and Frederic W. Goudy (1865 – 1947), a prolific American type

---

11 Ibid., p20.
12 A. F. Johnson, Type Designs, ed 3 (Jarrold and Sons Limited: Norwich, Great Britain, 1966), 54.
designer, have contributed to the study of actual physical representation of typography and have designed typefaces such as Copperplate (1905), Goudy Old Style (1915), LTC Remington Typeface (1929), Californian FB (1938) and many more that remain in use to present times. The ITC Berkeley Old Style type family was created in 1983 as a revival of Frederic Goudy’s California Old Style, and was specifically made for the University of California Press at Berkley. Morison described ‘type’ and ‘roman type’ in his 1963 publication *Letter Forms* as: ‘letters of the alphabet that are cast or founded for the purpose of impressing upon paper are known as “types”,’ and ‘roman type’ consists of the roman alphabet, uppercase, lowercase and small caps:

The normal roman type (in simple form without special sort, etc.) consists of an upright design, and a sloping form of it:

\[
\begin{align*}
&\text{ABCDEFGHIJKLMNOPQRSTUVWXYZ} \quad \text{abcdefghijklmnopqrstuvwxyz} \\
&\text{ABCDEFGHIJKLMNOPQRSTUVWXYZ} \quad \text{abcdefghijklmnopqrstuvwxyz}
\end{align*}
\]

**Differences between ‘alphabet’ and ‘letters’**

Frederic W. Goudy outlines the differences between ‘alphabet’ and ‘letters’ in his publication *Typologia* (1977). He says that: ‘The alphabet is a system and series of symbols representing collectively the elements of written language’\(^{13}\). Goudy’s analysis of letters led him to state that ‘letters are individual characters that compose the alphabet, each being primarily a representative form’\(^{14}\). The alphabet is the collection of letters; letters are separate entities and the alphabet is a collective of twenty-six letters of roman type. Goudy goes on to describe the other form or use of letters by saying that the letters represent a certain sound: ‘but this sound is definitely separate and not affected by any peculiarity in a letter form’.\(^{15}\) Because a ‘letter’ has two ‘representative forms’ or functions — one absolute and the other relative — each part will depend on two different human senses, one, the eye recognising the letter, or name, the other function is one of sound depending on where it is in a word. Recognition will depend on a reader’s reading ability, since the function of the letter gives no clue to the varying sounds it represents. Legibility is the ease with which the character can be identified and this is achieved by the design of the characters or their ‘physical aspects’ and understood (which is achieved by schooling and practice in typography) by linking the symbols to make sense of the puzzle of writing. Reading and writing ‘require schooling

---

\(^{12}\) Ibid., p.7.  
\(^{13}\) Frederic W. Goudy, *Typologia* (Berkeley, California, USA, University of California Press, 1977), 124.  
\(^{14}\) Ibid., p124.  
\(^{15}\) Ibid., p124.
and practice, the deliberate shaping of the brain”\textsuperscript{16}. The second function can only be defined by its use. ‘The form given a letter determines the degree in which it fulfills its first purpose, that is, its legibility, whereas the second is determined by its associates, by its position in a word, or by the varying relations of words with one another.’\textsuperscript{17} This may be illustrated by using the letter ‘s’ and its sounding in a different words, like in ‘his’ the ‘s’ sounds like a ‘zzz’, while the ‘s’ in ‘this’ sounds more like a ‘ssss’. Letters are abstract forms and have no particular significance until they are used singularly (ie ‘a’ ‘i’), or grouped together to make words: this is in effect the phonetic alphabets where characters are developed from their sound. The combination of sounds from different letters placed together can distort the sound of a single character as in the case of ‘s’ as just illustrated. E.C. Sanford in his research in 1888 ‘The Relative Legibility of the small letters’ outlines one aspect of the shortcomings in the legibility of the Roman alphabet, and this aspect goes back to the makers of phonetic alphabet:

The differences necessary to legibility have been neglected by the makers of phonetic alphabets, in their desire to indicate phonetic similarity by similarity of form.\textsuperscript{18} When characters are arranged in different positions they can produce different sounds for the same characters, and it is only in the complete form (words or sentences) that the true meaning (spoken sounds) comes out. The effect of the sound in words and sentences as opposed to sound of individual characters seem not to be taken into account by the phonetic alphabet makers, as the twenty six characters in the roman text produce an infinite number of words and sounds, and so the legibility of the characters depends on the layout and design of the overall text piece in combination with a clear distinct design for each character, i.e. ‘The physical aspects of the characters’ so they will not be confused with each other, this along with the knowledge of the reader will also aid in the readability of the text.

Goudy in \textit{Typologia} considers the question of legibility and the reasons why this subject was so neglected in the history of printing and typography. The fact that the form of the letters are not changing dramatically with use is because the reading public are content or seem not to want to change them but to work with what is there:

Is it because we are too much bound by convention, and have a disinclination to tamper with the traditional form of our letters; or are we deterred by belief that the

\textsuperscript{16} Nicholas Carr, \textit{The Shallows} (London: Atlantic Books, 2010), 51. See Chapter 1 Reading and writing at 51.
\textsuperscript{17} Frederic W. Goudy, \textit{Typologia} (Berkeley, California, USA, University of California Press, 1977), 125.
legibility we already have is as much as we can hope for; or are we inclined to let well enough alone, as it were, rather than to strive for easier readability?19 As already stated in Chapter 1, reading and writing ‘require schooling and practice, the deliberate shaping of the brain’20 and this has to take place before we read but once this is done there is no undoing it. Before we can read we speak, and reading and writing is translating the human invention of converting the spoken sounds into symbols. Speech becomes a habit, and a habit is a ‘recurrent, often unconscious pattern of behavior that is acquired through frequent repetition’.21 Our habits develop from birth and speech is inherited; a child learns to talk without instruction by virtue of his or her innate talent. At a certain age, for the majority of people, speaking becomes second nature, and the same applies when we start to read. We learn how to read and write, and take reading for granted and can read (operate) the letters and words as they are, and become legible to us. Edward Lee Thorndike (1847-1949) became one of the very first psychologists to be admitted to the National Academy of Sciences in 1917 and his law of effect ‘suggested that responses closely followed by satisfaction will become firmly attached to the situation and therefore more likely to reoccur when the situation is repeated’.22 While conducting research in the Teaching College in Columbia University he noticed that language teachers in Germany and Russia were using word count to match text with students. ‘The more frequent a word is used, they found, the more familiar it is and the easier to use’23 or the more it is used – using Thorndike’s ‘Law of Effect’ – the more likely it will be reread, so the more you read the easier it is to do so, and the more likely there will be satisfaction while reading and the more likely more text will be read, and as Thorndike’s ‘Law of Effect’ states ‘more likely to reoccur when the situation is repeated’. Where reading is repeated a reading habit develops, and this in turn can make the more frequent words more readable no matter what typeface they are in, the look, style and layout of the text will help with the legibility of the text. Around 1911 Thorndike began to count the frequency of words in English texts and the result of this was his publication in 1921 The Teacher’s Word Book, which listed 10,000 words by frequency of use. This list was used in further research into readability by Johnson in 1930 and Washburn and Morphett in 1938 and cited by Bond, Tinker and Wasson in Reading Difficulties: their diagnosis and correction.

19 Frederic W. Goudy, Typologia (Berkeley, California, USA: University of California Press, 1977), 123.
The printed word in any writing are merely symbols for the meaning intended by the author. These symbols serve as cues to the reader who must understand and organize an understanding of what is meant. The ease with which a child can do this depends largely upon his past experiences.24

The ease of reading is the readability of the text: ‘the readability has to do with how easy, difficult, interesting, or accessible its contents are, relative to the reader. When typography and other physical aspects are concerned, one speaks of legibility.’25 People with reading difficulties and for whom this does not work have to operate around the words that are used by the majority of people. It appears then, when taking the ‘invariance problem’ into account, readability is achieved by the reading habits of individuals and the design of the characters that make up words. The reader has to be able to identify the character to decode the words, as one cannot exist without the other, so it seems that the reading public is ‘bound by convention’.

Legibility is about the physical aspects of typography. The ‘physical aspects’ of typography are found in the way text is presented, for instance, by the shape of characters, spaces between and around characters, the length of the line of text, the size of text and the background it is presented on, or any other element used in the presentation of type. Printers, designers and typographers all work with these aspects of typography, and have learned their trade by experience and with the knowledge handed down from generation to generation since the invention of presenting typography by print from Gutenberg’s first production and even from the time of the scribes. Bror Zachrisson (1906-1983) in his publication Studies in the Legibility of Printed Text commented that: ‘The printer, type designer, layout man and typographical artist have had their say in the matter of legibility, though little consideration is paid to their comments in scientific literature’26, which is interesting since people in the printing and design industry work with typography and know their trade, producing legible and readable text (depending on use and in most instances). It appears that the assumptions that are used to produce typography that people will read and want to read, and accordingly, to produce typography that is legible and readable do not get the credit that they deserve as there is little or no scientific proof of their application. The use of ‘colour’ with typography is an example of this.

The effect of colour on print

Robert Bringhurst in his work *The Elements of Typography Style* stated: ‘the density of texture in a written or typeset page is called its colour. This has nothing to do with red or green ink; it refers only to the darkness or blackness of the letterforms in mass.’

![Univers typeface](image)

**Figure 10:** Shows Univers typeface from Black Extended, Black, Bold, Roman, Light and the oblique version of each family member. ‘All the forms and signs are printed in the same deep tone of black, yet the fine lines looks grey and a number of them together make a grey surface. The same type size looks different according to the spacing of the letters and the varying distance between the lines.’

He also commented that the colour of a typeset page or piece depends on four things: 'the design of the type, the spacing between the letters, the spacing between the words, and the spacing between the lines.' Not only does the shape of the characters affect the legibility of typography, but so does the colour of typography, and the colour of the background on which the type is presented. Again going back in history scribes and printers used dark type on a light background. ‘It is well known that the earliest printed books imitated late medieval manuscripts’ and also that ‘the early printed books looked so much like a contemporary manuscript that it was sometimes mistaken for one’, and this was done to give the reading public what they wanted and what they were used to reading or to put it another way what was accepted to be legible and readable. This was what was considered readable at that time based on what you read best you read most. The producers of the typographic pieces, books, and the like, had their market and their audience, and they knew what worked within the limitations and technology of the time, and in the case of books, used dark type on a light background. When the colour of typography is discussed it not only refers to the actual colour of type and the colour of the background (for this thesis the typography is black on a white background), but also refers to the evenness of colour dispersion on the page, so the influence of colour plays a part in the legibility of letters and figures, a physical aspect to make the character easier to identify and thus decode, see figure 11.

**PRINTED matter must be more than readable—it must be easy-to-read. This is particularly true of advertising literature. In that case it is more important to you than to your readers that your printed words be read. It is to your unquestioned advantage to have your printed matter as easy-to-read as thought and skill can make it.**

With the right type face chosen and the right size determined, the question of readability is still unsettled. Margins, space between letters, between words and between lines are almost, if not quite, as important.

Some folks think that the setting of a book page of “straight matter” is the easiest thing a compositor does. To my notion it is the severest test of his ability. To do a good job he has to decide questions about spacing with almost every line he sets. And you will realize what that means when we come to talk about spacing a few pages further on.

Consider this page. It is set in a good book face. The size is about right, but the uneven color, the lack of leads and the inequality in letter and word spacing make it harder to read rapidly and also less pleasing to the eye than the page opposite.

**Figure 11:** Reproduction of graphic shows the effect of colour from Benjamin Sherbow *Making Type Work* published 1916 page 86.

---

31 Ibid., p 23.
The text in the graphic explains and illustrates Sherbow’s view on colour and the layout of the page. There is uneven colour between the text and the background and this makes a page harder to read than an evenly spaced text giving an even colour. Sherbow states referring to the page as shown in figure 11: ‘Consider this page’. It is set in a good book face. The size is about right, but the uneven color, the lack of leads and the inequality in letter and word spacing makes it harder to read rapidly and also less pleasing to the eye.33

The aspect of colour has been investigated by several researchers in the search for legibility, for instance, Tinker & Paterson in 1931, Luckiesh in 1938 and 1941 and Ferree & Rand in 1940 and found that colour combination with a high brightness contrast gave the best legibility. Black type on a white background is easier to read than dark type on a dark background. This is a known fact, or an assumption born out of the working knowledge of typography for the printing industry and the reading public. So then why, as Zachrisson asked: does the scientific world pay little consideration to the designers’ and printers’ views on legibility? Is it that the design and printing world are more interested in the production and the experience with typography, and take such things for granted? Zachrisson in his experiments and research also found ‘that it is advisable to relate legibility to a particular group of readers, defined by age and experience. This seems obvious, but some of the results furnish new aspects on the matter.’34 He goes on to say that as a result of the research:

Our investigations suggest that it would be worth-while to continue studies of the legibility of printing text and its congeniality value on different levels of reading maturity and of education, as well as with different content material.35

The advance in technology and the changes from reading on paper to that on screen has given credibility to the Zachrisson’s statement that the change in presenting text on screen along with all the extra elements available on computer screens like hyper text, scrolling and linking to different files have altered what we traditionally know about legibility and readability on paper as opposed to that on screen. The advance in technology and the new medium for reading has opened up a new avenue to study into the legibility of text. New technology lends new potential for further research.

**Historical research into print based typography**

The historical research into typefaces was carried out on typefaces designed for print based typography on the technology in use at the time of the research, for example,

---

Roethlein used sheets of printed type available in 1912. The vast amount of research is based on specific print type but with the development of new technology research focused more on the use of typography in the electronic media and the need for the development of electronic typefaces was highlighted. The research of Zachrisson and others can be used as a starting point for continuing research into legibility. The research to date depends on existing typefaces, i.e. typefaces designed mainly for printing and with more recent studies typefaces designed for both screen and print use and for screen only. The categories of criteria Zachrisson used for his studies are outlined in the following table:

1. Objective
   - Size of letters. ‘Legibility coefficient’. ‘Specific legibility’.
2. Subjective
3. Functional
   - Distance threshold. Illumination threshold. Focus threshold. Speed of reading. Errors. Width of eye-span (i.e. visual angle subtended by the group of letters which can be appreciated in one eye-pause) or duration of eye-pause. No. of eye pauses per line. No. of eye-refixations (i.e. the fixation by the eye of a point a second time to correct an error in the first fixation. A return movement is involved). Regularity of eye-movements. Reading rhythm.36

These categories have also been looked at through theoretical and analytical research carried out in laboratories under controlled scientific conditions. The difference between this research and other research undertaken with a positivist methodology was that Zachrisson’s results were examined by persons with a working knowledge of typography, by using traditional typographic assumptions of legibility and readability of typography as opposed to persons with a scientific background with little or no background in typography. The source matter is appropriate for the experiments as the assumptions or experience of working knowledge of typography by Zachrisson’s selection of material in the ‘right type for the job’ produced research that benefits the reading public, and to produce typographical material that they will read and want to read, for example, a display typeface would not be selected for use for the legibility of continuous text, as can be seen in figure 21, page 68. This figure illustrates that typefaces designed for display are not very legible at 9pt–12pt these being a common size used for continuous text, as can be seen in most continuous text that the reading public read. Perhaps, a better basis for determining the issue of legibility of reading material is the one provided by Zachrisson whose criteria cover such a wide range of practical topics consisting not only of type, but also of length of line, leading, colour

---

and contrast, distance or size, illumination and paper surface. The following factors are related to typography and to those technical factors identified by Zachrisson in the Studies in the Legibility of Printed Text in the Graphic Institute in Stockholm 1965.

1. Type: (a) design, general shape; (b) boldness, caps etc.; (c) width; (d) caps or lower case; (e) roman or italic; (f) roman or Fraktur.
2. Length of line.
3. Leading.
4. Colour and contrast.
5. Typography: (a) spacing of words; (b) margins and column distance; (c) artistic presentation; (d) arrangement of sentences.
6. Distance or size.
7. Illumination and paper surface.

As stated ‘the readability has to do with how easy, difficult, interesting, or accessible its contents are, relative to the reader.’ Reading ‘requires schooling and practice’ and with schooling and practice the act of reading becomes easier, and text that has not being practiced or is completely new will not be as easy and thus not as readable. So not only does the research carried out by Zachrisson and his team contribute to legibility research, his Studies in the Legibility of Printed Text also includes previous experimental studies into legibility and readability from the 1960s. But he admitted that the information gathered does not give a complete picture and left gaps for more research, but all this came before the new technology of Macs and digital typography. Zachrisson also outlined factors that related to reading and these factors should be considered and included in future research to give a more complete rounded result.

2. Text. Purpose: Recreation or work-type. Length
3. Typography and technical factors. Appropriateness of technical means used.
4. Situation. Oral or silent reading. External conditions (lighting posture, environment etc.).

Zachrisson’s studies were carried out on commercially produced typography, as this was the typography available to the reading public, i.e. the type available for commercial printing at that time. But his research related to the 1960s only. Any research for the present need had to be carried out on the type available for commercial printing and screen presentation. The technology for typography and presenting typography has dramatically changed since the 1960s. Since the availability of

---

computer and digital typography the only common ground present day typography shares with former typography is that the terminology and the basic shape of characters have remained the same since Gutenberg’s time as illustrated in figure 13. The technology to produce typographical images in the 1960s can trace its roots back to Gutenberg.

Between the 1440s and the 1960s there are several important milestones in the development and imaging of typography. Linn Boyd Benton, an American type designer and inventor, whose invention in 1885 was one of these significant developments and without this invention we would not have companies developing the typographical industry as we know today. In 1885, Linn Boyd Benton invented a punch-cutting machine. This machine was a typographical invention as fundamental as the mould of Gutenberg (c.1440). Neither Linotype nor Monotype would have been possible without Benton’s invention. Linotype and Monotype led the way in developing typography, and by default also with the development of type and the means of setting type, which have had an indirect effect on the legibility and readability of typography. When typography is no longer restricted to individual metal characters with set space around them, or setting the type in lines and producing a new cast for each piece required for kerning see figure 12, the altering of type is not as big a job as in former times. But with the availability of computers and electronic typography to the general public the control of the presentation of typography is put into non-type skilled hands, and when the knowledge accumulated over the generations of working with type is excluded this can produce strange and not always satisfactory results. Unlike the Linotype system, kerning was possible in the Monotype system, thus giving visual even spacing between words and characters (improving the colour of typography) thus aiding the even movement of the eye while reading which aided readability. The following is a brief outline of the development of the then new technology (1886) for setting type.

The day Ottmar Mergenthaler demonstrated the first line casting machine to the New York Tribune in 1886, Whitelaw Reid, the editor, was delighted: “Ottmar,” he said, “you’ve cast a line of type!” The editor’s words formed the basis for the company label, and marked the beginning of Linotype’s success story. Four years later, the ingenious inventor founded the Mergenthaler Linotype Company. …Today, Linotype has one of the world’s largest font libraries, offering more than 10,500 high-quality typefaces. Linotype’s goal is to be a partner for designers and typographers, and to support a global transfer of know-how and an open exchange of ideas and information in the field of typography. … With the

---

revolutionary invention of hot-metal setting, fonts were no longer just for the elite and soon became a popular tool of graphical and visual communication.\textsuperscript{41}

It appears that with the advance in technology and the availability of typography moving out of the hands of professionals ‘fonts no longer just for the elite’ with the availability of electronic typography on computers to the general reading public the need for legibility is more important than ever.

Layout and typographical design

David Jury in his article ‘Convention and Creativity in Typography’ stated: ‘The role of convention is to diminish the influence of noise. “Noise” might be defined as anything that comes between author and reader: poor light, uncomfortable chair, bad printing, errors of fact, unconventional (and therefore, unpredictable) layout, etc.\textsuperscript{42} Legibility and readability can be aided by several factors. Readability in particular can be improved, for instance, with knowledge of the subject being read, or if the reader understands the subject and the terms for that subject, the text will be more readable than if the person does not understand the subject then the text would be a hard read. Fatigue is another factor that can affect the readability and legibility of text. These factors have been researched in the search to find the optimum readability and legibility by, for example, the research of Louis-Émile Javal in the 1880s, H. Cohn in 1883, Huey in 1910, Kirschmann in 1917 and Carmichael and Dearborn in 1947 to mention a few. Others factors examined include the look of typography contexts, this underpins the assumption that certain types are better than others, and if a type is ‘better’ and an easier read it does not cause as much fatigue while reading. In 1790, Jean Anisson in an experiment showed that a page set in Garamond could be read from a point further away than a page set in Didot type of the same size. The reason for the experiment was that Anisson ‘disliked the new Didot design and was apparently motivated by a desire to prove that Garamond type was more legible’.\textsuperscript{43} A pleasing or an appealing look of a typeface is another factor that may be considered in relation to legibility and readability. The aesthetic value of a typeface can make the typeface more pleasing to the eye, more comfortable ‘easy-to-read’ and thus on the bases of the fatigue factor can make a typeface more or less readable: W. Morris in 1896 and S. Morison in 1924 studied the contrast of thickness and thinness of type limbs from an engaging look, point of view.

\textsuperscript{43} G. Thomas Tanselle, \textit{Bibliographical Analysis, A Historical Introduction} (United Kingdom: Cambridge University Press, 2009), 110.
Typography, the practical and applied side of language and reading, can also possess an aesthetic value, ‘There are two kinds of beauty: free beauty (pulchritudo vaga), or beauty which is merely dependent (pulchritudo adhaerens). The first presupposes no concept of what the object should be; the second does presuppose such a concept and, with it, an answering perfection of the object.’44 Not that typography is perfection but it does serve the purpose of communication and illustrates verbal speech in the form of words. The laying out of pages of typography in a way that makes the type ‘easy-to-read’ aids in attracting a reader to a book, ‘type designers are but human. There is opportunity for the exercise of judgment in the selection of the right face of type, not only to secure an appropriate and pleasing appearance, but also to secure proper legibility.’45 The comfort of a reader when reading aids in legibility and readability together with the good layout of a book/page, for example, having sufficient space between line to prevent ‘doubling’ (reading a line twice) and having a line at a sufficient length for the size of the type. The aesthetics of a book will also benefit the printed matter ‘built without affectation, with little but regular spacing between words; a contraction is better than an overcrowding of the line; breaking a word in preference to spacing out the letters.’46 The position of the printed matter on the page also assists in the comfort of the reader and thus the readability of the book. It is assumed by typographers then an aesthetic book aids in the readability of it. The arrangement of the words can also produce beautiful books. Germans readers [until the 1940s], for instance, found it easier to read Fraktur or Schwadacher, because they had been accustomed to doing so from youth. Irish or English people would find these typefaces hard to read in continuous text because you read best what you read most goes for words as well as typefaces. The principle of Thorndike’s list of 10,000 words used in certain readability research also apply to typefaces and show that familiarity with a typeface aids in making a typeface readable. People develop a liking for different typefaces and express preference when working with type.

Preference for typefaces such as Times Roman exist by habit, because these typefaces have been around longest. When those typefaces first came out, they were not what people were used to either. But because they got used, they have become extremely legible.47

Edward Johnston (1872-1944) by his teaching and practice almost singlehandedly revived the art of formal penmanship which had lain moribund for four centuries.

Johnston’s major work, *Writing and Illuminating, and Lettering*, first published in 1906, claims that the essential virtues of good lettering are ‘readableness’, beauty and character:

The first general virtue of lettering is *readableness*, the second, *fitness* for a given Use. … The qualities on which these virtues seem chiefly to depend, and their special signification in the case of plain writing, may be set forth as follows: —  

1. **Simplicity**: As having no unnecessary parts (and as being simply arranged).  
2. **Distinctiveness**: As having the distinguishing characteristics of each letter strongly marked (and the words distinctly arranged).  
3. **Proportion**: As having no part of a letter wrongly exaggerated or dwarfed (and as the lettering being proportionally arranged).  

In the light of what was said typography exists to represent the spoken language and for typography to do its job it must be read and understood. Typography depends for its proper effect upon various qualities in the face of type selection its readability, colour, distinction of design, and these are all selected from the knowledge of typography accumulated over years. Having the right type for the job is not enough to achieve the goal of typography that of being read and understood, but other aspects have to be taken into account as well because it is not just one thing that can make a piece of continuous text legible and readable, it depends also on its size, spacing, arrangement and its combination with other types.

**Examples of typographic design going wrong (or not using the right type)**

Robert Bringhurst in his work *The Elements of Typographic Style* stated: ‘Letterforms have tone, timbre, character, just as words and sentences do.’  

Several design features and formats should be incorporated when working with typography. Whatever makes typography easy to read will aid the readability and legibility of the piece of text. For example, ‘good practices’ as illustrated by figure 17, page 60, shows the effect of wide word spacing and closer spacing in text. The wide and uneven text is not as easy or comfortable to read because of the closer spacing in text. In figure 18 page 62, which shows the different spacing between lines, and as Benjamin Sherbow stated ‘enough space should be put between lines to make them inviting and easy to read. Stop when this has been done—don’t overdo’.  

Different typefaces also require different leading and letter spacing due to the different length, widths and style (serif, sans serif or script) of typefaces — however it is not a case of one rule or convention fits all. Also having the right type for the correct use will make the typography work as a unit. This goes for

---

all bodies of text be they handwritten, printed, or read from a screen. The right type, i.e. ‘fitness for use’ is a very important aspect. ‘Since type can suggest certain things not merely by what the word says, but how they look in print’\textsuperscript{51}. An example of this would be a warning sign that needs to be visible, demand attention and easy to understand, and for this reason most warning signs are created with heavy clear typeface and sometimes in all caps: WARNING and not done in a light personal type, in say a script typeface: \textit{warning} (both of the warnings are set in the same point size). Both warnings say the same thing but the one stands out more than the other, also both can be read and understood, but the first one ‘WARNING’ will be acted upon by looking more of a threat and taken notice of because of this. The right type can be a typeface that suggests something of the character of the subject of the text, for example, in the advertising of a product, or to convey a message in a certain tone. An incident involving the wrong typeface or format causing problems is documented by Simon Garfield, award-winning British journalist and non-fiction author in his book \textit{Just My Type}. In New Zealand on 25 September 2009 Vicki Walker who worked for ProCare in Auckland as an accountant lost her job and almost her sanity as a result of sending an email in all caps, bold and red. The email was as follows: \textbf{TO ENSURE YOUR STAFF CLAIMS ARE PROCESSED AND PAID, PLEASE DO FOLLOW THE BELOW CHECKLIST}. Walker was dismissed three months after the email was sent to fellow employees because it was deemed to have caused ‘disharmony in the workplace’. After re-mortgaging her house and further borrowing of money from her sister in order to fight her court case for unfair dismissal, she succeeded in appealing her case, and was awarded $17,000.\textsuperscript{52} Since the start of producing text by printing, understanding the need of the general public for books, reading material, etc. has led printers to produce publications within the limitations of print that appeal to the reading public and take account of what the reading public want to read. Alterations have been carried out in typographical layout to produce more legibility, in the size, length of line, leading and spacing, and an example of this is to be found in the work of the 1450s printers of Latin texts, whether scholastic, theological or classical. The printers used a less formal letter following the style of manuscripts with the typeface being rounder with more open letters with descenders like roman, and this was called Fere-humanistica or Gotico-antiqua. Therefore, it seems that the look of the characters matters as much as what the words say. Ignoring this fact may cause problems for the designer of the material, as in Vicki Walker’s case that resulted in the

\textsuperscript{52} Simon Garfield, \textit{Just My Type, A Book About Fonts} (London: Profile Books, 2010), 30-32.
loss of a job and a long court case. ‘Some of the best designs in memory reveal the
design to be married to the content, where a message is not just visually enhanced but
elevated in meaning.’

A. F. Johnson and typography design

A. F. Johnson (1884—1972) was for some forty years an Assistant Keeper in the
Department of Printed Books in the British Museum and published many articles on the
history of printing and typography. His book, *Type Design* (1934), is now a standard
work in the field of typography. The book is a study of typographic design from the
invention of the art of typographic design up to the nineteenth century. Johnson explains
the typeface Textura and the changes made to it so as to increase its legibility.

The effect of the increased height of the ascenders and length of the descenders is
to add to the amount of white on the page and to impart a lighter appearance in
comparison to Textura. There is a greater differentiation of letters and therefore
increased legibility. (Textura — the standard letter in German for Bibles and
service books; it is the type of the 42-line Bible, the 36-line Bible, the Mainz
Psalter of 1457, and of all the early Missals in the fifteenth century).

Typography is constantly developing along with technology and adapting to the needs
of the day. ‘Ever since Gutenberg, typographic design has developed in direct
relationship to the advances that have taken place in graphic arts mechanization and
technology,’ i.e. from hand set metal to mechanical machine-set over a hundred years
ago to electronic film-set era in the 1960s to present day digital typography. Each new
technology produced its own restrictions and advancements. Typography is no longer
restricted to metal form set in specific blocks and this has given typography more
freedom as can be seen with digital typography: kerning and tracking can be done at a
click of a mouse or a few keys on a key board, also leading or the space between lines
of text is not constrained by the metal structure of characters. The hard and software
give the operator the facility to manipulate type and the spacing around it, and if there is
little or no working knowledge of typography there can be unfortunate consequences as
with Vicki Walker (2009) losing her job as the result of red, bold and caps text in an
e-mail to her fellow workers. The basic characters stay the same and the terms used to
refer to typography have basically stayed the same since the 1440s. There are however
ongoing modifications to typography to please the public, and terms have taken on
different meanings but these terms are still in use (see figure 12 page 49 and quote on

Publisher LLC, 2005), 19.
55 John D. Berry, editor *U&lc: influencing design & typography*, ‘Typography and the New Technology’ *U&lc Volume One,
Number One, 1973* (New York: Mark Batty Publisher LLC, 2005), 33.
kerning, below). Designers, printers and type designers cater for the reading public and provide material they will read and want to read, and this practice was the same in the 15th century when the printers ‘wily men of commerce that they were, passed their products off as the manuscripts they were replacing’\footnote{Margaret M. Smith ‘The design relationship between the manuscript and the incunable’, 23-43. A Millennium of the Book, Production, Design & Illustration in Manuscript & Print 900-1900 edited by Robin Myers and Michael Harris (Hampshire, England: St Paul’s Bibliographies, 1994), 23.}, so as not to confuse the reading public, and further to give the reading public books in the size, shape and text style they were used to.

The historical meaning of kern is somewhat different from the digital sense. The kern is the part of a piece of metal type that overhangs beyond the body (the ‘shank’) so that it can rest on the body of an adjacent character, allowing for tighter spacing and better letterfit.\footnote{Kerning Text Type’ Photographs: Lead Graffiti. Accessed March 25, 2014. Available \url{http://www.fonts.com/content/learning/fontology/level-2/text-typography/kerning-text-type}}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{metal_type_with_kerns}
\caption{‘Metal type with kerns makes all the difference in the spacing between certain character pairs, such as ‘rf’, ‘fe’, and ‘ct’ (lower)\footnote{\textit{Ibid.}, \url{http://www.fonts.com/content/learning/fontology/level-2/text-typography/kerning-text-type}}. Source: ‘Kerning Text Type’ an article commissioned and approved by Monotype Imaging Inc. Photographs: Lead Graffiti. Accessed March 25, 2014. Available \url{http://www.fonts.com/content/learning/fontology/level-2/text-typography/kerning-text-type}}}
\end{figure}
As printers became familiar with their trade, together with a greater understanding of the limits and restrictions of metal type, they refined their materials and tools with type to improve the ease of read of type (see figure 12, is an example of how the characters were modified or kerned to improve the spacing between characters). As described above, the addition or reduction of white space allows better letter fit, and thus aided legibility. Another addition of white space to the counters helped in the printing so the counters would not fill up with ink and give a clean character thus aiding the identifying of characters and the legibility of the character. This can also be seen in action with digital type where the counters are made larger so small type can be see more clearly, and an example of this is Matthew Carter’s Verdana dating from 1994 see figure 20 page 66. When people are reading text that is easy on the eye they are more inclined to continue reading. It is assumed by typographical designers that books with the right size type, the right style typeface, correct line length and clear distinct characters all help to aid and guide the eye when reading; the easier a book is read the

---


---

**Figure 13:** Showing parts and names of metal type. Source: Legros & Grant. ‘Typographical Printing Surfaces.’ (1916) p. 11.
more enjoyable the experience it is for the reader. Text easily read answers the criteria for legibility and readability. Typography and typefaces are to be seen, and not to be noticed ‘the type must be pleasing, while at the same time it should not make its presence felt’⁶⁰, and if typeface is noticed it takes away from it true purpose, i.e. that is to present the phonetic sounds of the spoken word. ‘A type which is to have anything like a present, let alone a future, will neither be very “different” nor very “jolly”’.⁶¹ If the typeface and layout are noticed the contents of the text will lose out. The raison d’être for typography is readability, i.e. the written language. This is explained in a quote from the Linotype Company of type’s highest purpose, i.e. to be read:

> Because of the time required to read most books and the consequent demands placed upon the eyes, legibility is of prime importance. But in addition to being easily read, the type must be pleasing, while at the same time it should not make its presence felt. When readers become conscious of the type in a book, its selection and arrangement fall short of its highest purpose.⁶²

### Changing the typographic fashion

A familiarity with typography will also give rise to a ‘type’ habit, i.e. a conditioning to be able to read that typeface. Linotype Company with their expertise in typography outline another great influence on reading ease:

> Another great influence upon reading ease is habit. It is conceded that those types which have been read from childhood are the easiest to read. That is, Germans [until the 1940s] find it easy to read Fraktur or Schwadacher, because they have been accustomed to doing so from youth. English speaking and reading people find these letters difficult to read, except after lengthy familiarization. The same can be said of italics. Aldus set entire books in italics and won considerable acclaim. At a later period other printers began using italics in combination with roman for titles and front pages. However, the people had become accustomed to the use of roman letters in text pages and it is a rare instance to find a well composed book set entirely in italics. The habit of readers have been formed.⁶³

Typography, like other inventions and designs, has fashions and fads, yet the readability and legibility of a typeface continue to depend on differing factors, and one of these is that ‘you read best what you read most’. The Germans [until the 1940s] found it easy to read Fraktur or Schwadacher, because they had been accustomed to doing so from youth but Irish or English people would find these typefaces hard to read in continuous text. William Morris’ (1834 – 1896) writings on typography, many of which were originally given as lectures to the Bibliographical Society and the Society of Art in

England, reveal a great knowledge of the history of printing. Morris’ books are a modern variation of the early printed books of Northern Europe but those books were also mere mechanical variations of manuscripts that preceded the invention of movable type. Morris was an English textile designer, artist, writer, and socialist associated with the Pre-Raphaelite Brotherhood and the English Arts and Crafts Movement. He based his Troy and Chaucer typefaces following a revival of Fere-humanistica from the 1500s. These typefaces were based on the types and style of gothic hand style types existent in the 1500s. Fraktur or Schwadacher are both Gothic style (Blackletter) typeface. It seems that the reading public were not familiar with these styles of typeface because they were unaccustomed to them and, as a result, they were not a success with the reading public in the 1800s. The Kelmscott Press founded by Morris and published 53 titles (18,000 copies in all) with these typefaces. Kelmscott Press was never a financial success and only lasted for seven years and closed in 1898. All of this re-emphasises the assumption: you read best what you read most. The public were not used to these typefaces and voted with their pocket.


---

Simon Garfield outlines the views of present day typographic designers and also the background of typefaces such as Helvetica and Comic Sans. Zuzana Licko, publisher of *Emigre* magazine founded in 1984, received much critical acclaim when the magazine began to incorporate Licko’s digital typeface designs created with the first generation of the Macintosh computer. Licko is credited with saying that:

‘You read best what you read most’. She went on to say: ‘Preference for typefaces such as Times Roman exist by habit, because these typefaces have been around longest. When those typefaces first came out, they were not what people were used to either. But because they got used, they have become extremely legible.’ The association of legibility with familiarity or habit has been taken for granted by typographers, as illustrated in statements from Eric Gill and Zuzana Licko. Eric Gill, designer of Gill Sans, one of the twentieth century’s earliest and classic sans serif types, was of a similar frame of mind when he said: ‘legibility, in practice, amounts simply to what one is accustomed to’. This view is again echoed in *Stop Stealing Sheep & find out how type works*, a publication by type designer Erik Spiekermann and former manager of Adobe Originals Type Group along with E. M. Ginger writer, editor, typographer, reviewer, designer, instructor, bibliophile, and weekend printer: ‘We read best what we read most, even if it is badly set, badly designed and badly printed. … certain images are deeply ingrained in the reader’s mind.’

Samuel Hayes’ *Practical Treatise on Trees* originally printed in 1794 is an example of changes in the shapes of character over time. When this book was typeset it was set in typefaces that were familiar to the reading public of 1794; the typefaces used had the lower case ‘s’ looking more like the present day lower case ‘f’. The present day reader would find the first few chapters uncomfortable and not an easy read as the present day reader would not be familiar with the lower case ‘s’ looking like an ‘f’, thus reducing the legibility and readability of the book. However, with exposure to the unfamiliar characters a new reading habit is developed, and the reader becomes familiar to the look of the 1794 ‘s’ thus registering a new (or old) character in the reading/alphabet. The reading public’s habits can change with exposure to altered (modified) characters thus they become accustomed to, and familiar with, new type. As stated: ‘legibility, in practice, amounts simply to what one is accustomed to’ and readers in the 21" century are not accustomed to having their ‘s’ looking like an ‘f’.

---

66 Ibid., p60.
this practice.—It is not indeed an easy matter to ascertain the best season for removing of trees, so much depends on the nature of the soil and situation.—In stormy situations I prefer planting in spring; but trees planted at this time will require more watering: in general, we may say, that with few exceptions (amongst which, I think the ash is one, which though apparently a very backward tree, seems to be injured by removal late in spring) all the deciduous trees may be planted in any month between October and their time of shooting into leaf; and Millar, in his early editions, mentions the beginning of May, as the best time to plant oak.—Boucher and Lord Kaims agree with him; and I have followed that practice for several years with such great success, that I venture highly to recommend it.

Out of some thousand oak, transplanted the second week in May, from a seedling-bed at Mr. Edgar’s nursery near the Foundling Hospital, where they had stood in that rich soil till above four feet high scarcely one failed though carried thirty miles to a high situation in the county.

Figure 15: Samuel Hayes’ *Practical Treatise on Trees*, facsimile edition published 2003 by New Island, Dublin, Ireland originally printed in 1794 page 26 showing the lowercase s looking like a lowercase f.

Figure 16: Headings from the “Ship of Fools” Latin translation printed in 1497. While these headings were familiar and as a result, legible to those living in the fifteenth century, they would not be so decipherable in modern times, for example, lower case c and lower case r are very similar, making the text a hard read.
‘Legibility is a dangerous – and interesting – word’

Legibility is about ‘the physical aspects’ of the typography, but this is not just restricted to the design of the characters as it is also about the design and layout of the text as can be seen in figure 17 and 18 (pages 60 – 62), and the spacing is just one ‘the physical aspects’. Thus legibility is aided by design and layout or design and layout taking into account the need of the typography to be comfortable and an easy read (not all typefaces are designed to be an easy read, the design job might need the text to be illegible to draw attention and get the audience to work at reading the text). Ruari McLean (1917 – 2006) was a leading typographical designer of his day whose work encompassed stationery, comics, magazines and fine books. He succeeded Sir Francis Meynell as Typographic Adviser to the Stationery Office (1966 – 1980). He was also a freelance typographer and the author of numerous publications on typography and design. McLean outlined his view on the meaning of ‘legible’ in typographic design and the complex issue it can be, from a practical point of view:

‘Legibility’ is a dangerous — and interesting — word. It is dangerous because it is so often used as if it had a definitive or absolute meaning, which it does not have. … If you say ‘that is legible’, you mean only that you can read it: you do not know whether I can. … In typographic design, ‘legibility’ is the word used to define a desirable quality in typefaces, lettering, pages of books, posters, road signs and words in any form. … When discussing their own work, and in particular book pages, typographers use the word ‘legible’ to mean ‘easy read’…

Legibility is a sort of a movable feast with no ‘definitive or absolute meaning’ and several aspects have to be taken into account to achieve an ‘easy read’ or to be readable for the audience for which it is intended. Depending on the use of text, legibility is achieved by different means (viz., leading, size, colour, position and presentation) and its success depends on the ease with which the eye can identify letters and distinguish them from one another, and these means are in the hands of the type designer and the designer or printer. Hill’s view on how designers apply legibility to text matter is ‘probably best viewed as a body of knowledge, research and opinion to which designers refer selectively, rather than a subject governed by any single unified theory or categorical law.’ Designers lay out typography depending on the requirement of the end user drawing on the ‘a body of knowledge, research and opinion’ from working with typography aimed at a specific audience and to give the best legibility to that audience. ‘Readability has to do with how easy, difficult, interesting, or accessible its

---

contents are, relative to the reader.72 One of the factors that determines whether a book or body of text is readable is the intelligence of the reader. Where there is not an interest or the contents of the text is not engaging the reader will indeed find it a very hard read no matter how easy the eye can identify letters, so legibility does not improve the readability of text but does aid in the identification of text and word. Several other factors are used to aid readability and these include leading, size of type, choice of typeface and layout, and this is where there is where the two separate and distinct concepts of readability and legibility interact with each other, and in a way they are dependent on each other.

Over the centuries of printing with moveable type which increased the availability of books to the general reading public there has been a search for the ‘perfect typeface’ to aid legibility. Such research was conducted by M. Motteroz a Parisian printer in 1876, and Eric Gill who designed classic typefaces during his life time (1882-1940) and which are still in common use today, and Matthew Carter who in 1995 won the AIGA medal for design for his typeface for the roman type, Hebrew, Greek and Devanagari typefaces. Carter trained as a punchcutter and went on to design important typefaces for present day technology such Verdana and Georgia for Microsoft that are ‘tuned’ to be extremely legible even at very small sizes on the screen. Typefaces have been designed for specific jobs such as Bell Centennial designed by Matthew Carter in 1975-1978 for AT&T’s for use in telephone directories. Bell Centennial was designed to be legible at a small point size and to get the large amount of character per line and yet not lose on legibility. What is needed is the right typeface for the job at hand, and type legible for one particular purpose might not be so for another, many typefaces we use today are designed for particular jobs or situations. In 1876 M. Motteroz looked at the matter of typographical legibility from the viewpoint of an experienced printer with years of working experience with typography. The typeface Motteroz designed was based on his conclusions and resembled the letters of Bodoni and Firmin Didot and is called the Motteroz types. His research was carried out with the aid of the reading public so as to reflect the views of the reading public, and not just people who had a vested interest in the results.

By a series of experiments undertaken with readers entirely unconnected with printing he arrived at the conclusion that types are read with less fatigue if they are: [a] rounder, [b] more equal in thickness, [c] the upstrokes [ascenders] shorter, [d] each letter unlike any other, [e] the long letters well proportioned to their own

body. … The Motteroz types were chosen by the Municipal Council of Paris as the most readable letter for its school books and official publications.\textsuperscript{73} Motteroz’s typeface is an example of a type designed for a specific reason and purpose. It was designed for use in books, taking account of the views of the reading public who took part in the experiments and combining them with the traditional knowledge of typography. This typeface was recognised as the most readable letters for school books and official publications by the Municipal Council of Paris in their search for a suitable typeface for their needs. The typeface was constructed from the working knowledge and experience of working with typography, and thereby showing that the research done by an experienced typographic practitioner can be successful in creating readable typography even though the research was not done in a laboratory. This may be viewed as an example of the relevance of a working knowledge of typography and why account should be taken of the comments of printers, type designers, layout personnel and typographical artists have to say on the matter of legibility in scientific literature. As Zachrisson in his 1965 study on legibility stated:

The opinions of people in practical work are often as conflicting as some of the results presented by scientific studies, they should not be ignored. Letters are designed by artists, type are cut by the type-founder and printed by the printer, and the results of these activities are habit-forming reading instruments.\textsuperscript{74}

‘In typographic design, “legibility” is the word used to define a desirable quality in typefaces, lettering, pages of books, posters, road signs and words in any form.’\textsuperscript{75} There is no definite answer to the question of legibility only ‘a desirable quality’, and it together with a combination of other elements give the reading public an easy read. Research into subjects can take different forms and different forms of research can contribute different facts or elements to the overall subject. A desirable quality can be achieved with the aid of traditional knowledge accumulated over years of practical working skills, and this is no less relevant than research found as a result of experiments done in a laboratory. Producers and companies engaged in working with typography and print have put their views about typography into print. The following extracts are some of the views from a Linotype Company publication as well as typographers, printers and the typography trade, with knowledge handed down from over 500 years of printing.

Legibility of type is a matter of consequence to the millions of readers throughout the entire world. An increasing appreciation on their part is manifest in many directions and undoubtedly evinces the efforts of designers, manufacturers and

\textsuperscript{73} Frederic W. Goudy, Typologia. Berkeley (California, USA, University of California Press, 1977), 147-148.
\textsuperscript{74} Bror Zachrisson, Studies in the Legibility of Printed Text (Sweden: Almqvis & Wiksells Boktryckeri AB, Uppsala, 1965), 34.
\textsuperscript{75} Ruari McLean, The Thames and Hudson Manual of Typography (London: Thames and Hudson Ltd, 1997), 42.
printers to bring the typographic arts to a high plane of excellence. Psychological tests have proven that eye fatigue is the result of a complexity of nerve reactions while reading. It has shown that neither large type size alone nor apparent legibility have proven always to be the easiest to read. Pleasing letter design, interesting subject matter and its arrangement play a defining part in both reader acceptance and eye fatigue.  

Again in the publication *The Readability of Type* (1947) it was stated: ‘While studies continue in the subject of legibility, and standards are raised even higher, experience, experiment and common sense will be the controlling factors among printers and publishers.’  

*The Readability of Type* also acknowledges the accepted fact that reading is done not by letters but by groups of letters or word-forms. This is further backed up by Erdmann & Dodge (1898) research:

A character rendering, alone by itself, may be legible and pleasing, but when combined with others of the same design may fail to justify the expectations of its originator. Conversely, there have been examples of seemingly faulty characters designed which upon being grouped with their fellows have produced satisfactory effects. Notable among such is Caslon, one of the most widely used and popular faces over a long period of time.

A realization of the group form of eye action, combined with the proper selection of type face for the purpose at hand, the length of lines when set and the adequate spacing between lines constitute to a considerable degree the basis of the legible composition of type.

The experience and knowledge of working with typography produced the source materials used for the scientific research into typography and this in itself gives credibility to the typographic designers and should also be taken into account in the scientific view of legibility as the design of the characters contribute to the legibility of the characters giving a desirable quality to, and provide the reading public with text they will read and want to read. Donald Knuth’s mathematical analysis of algorithms and inventor of literate programming points out that ‘…it is clear that the mathematical definition of letter forms has a long history. However, I must also report near-universal agreement among today’s scholars of typography that those efforts were a failure.’  

This could be the result of the fact that original characters are based on the scribe’s characters and have changed little in essential form:

A letter is a symbol of unity that has comedown to us with but little actual change in its essential form since the invention of typography. There remains, then, very little which may be changed, since we may not foist new or strange characters into an intellectual currency already fixed by long use.

---

78 Donald Knuth, *Digital Typography* (CSLI Publications: Stanford, California, 1999), 38.
79 Donald E. Knuth, *Digital Typography* (CSLI Publications: Stanford, California, 1999), 38.
The characters are designed by people such as Matthew Carter who is credited with stating that ‘technology changes faster than design’ new typefaces are designed for new technologies but the design and knowledge on typography dates back to the 1400s, the human element having a very large say in the design and because of this the human input cannot be removed from the equation. The human interaction when operating type and the habit developed is another reason why the working knowledge of typography should be explored and included in research on typography.

Tradition itself goes more deeply into the very principles of art and life. The aim of art is to make a useful thing beautiful; tradition not only teaches the best way that has been found to do it, but shows also the metes and bounds of man’s endeavor reached at the moment, the walled boundaries within which the imagination of the craftsman may have full sway.  

‘Type is to be read’. Reading is the combination of letters in words to convey the written language. Tradition has guided typographers to assume that for reading large numbers of words or continuous text, several elements should be included, viz. the right typeface for the job, the correct point size, correct line length (between 10 or 12 words), and if the line is too short the eye will have to travel back too often and this breaks the reader’s rhythm, and if the line is too long it can make it difficult to continue from the correct line in large blacks of text, acceptable leading, see figure 18 (page 62), (where in continuous text the leading – space between lines, is larger than the space between words) and word and letter spacing, see figure 17 (page 60). There are many different types of reading: a novel, an academic book, poetry book, dictionary, all of which are read in different ways and all need to be treated as individuals. A simple example to explain this is to be found in young students books where the typeface needs to be larger than in a book for an experienced reader, and what is important is that the reader finds the text readable depending on age and reading experience. Anything that takes from this goal is counter-productive. The text serves the main purpose of reading but if its presence is made too overbearing it takes away from the reading experience. So even though one sees text and identifies each character, one should not notice the characters as individuals but as part of a word and sentence:

Aldus’ and Caslon’s are both relatively feeble types, but they represent the forms accepted by the community: and the printer, as a servant of the community, must use them, or one of their variants. …If readers do not notice the consummate reticence and rare discipline of a new type, it is probably a good letter. But if my friend thinks that the tail of my lower-case r or the lip of my lower-case e is rather jolly, you know that the fount would have been better had neither been made.

A type which is to have anything like a present, let alone a future, will neither be very ‘different’ nor very ‘jolly’. 83

The following is an example of words drawing attention to themselves with bad word spacing and the words distracting from the overall meaning or goal of text, to be read.

When words are spaced as in this paragraph it is like setting each word off by itself to be looked at separately. That makes reading more difficult. And when words are wide spaced in one line and close spaced in the next, the reader may not know just what is the matter, but he knows that the print is not so easy to read as it would be if set as in the following paragraph. The closer spacing of the words in this paragraph not only make a sightlier page but also makes print easier to read. And it really saves space to set words reasonably close—space that you can use to better advantage between lines of type. Note for instance, the difference between the two lines that follow:

First and last make it easy for the reader.
First and last make it easy for the reader.

Figure 17: Reproduction of the graphic shows the effect of wide word spacing, closer spacing the text is an extract from Benjamin Sherbow’s Making Type Work published 1916 page 92. 84 (Scan of original in Appendix Two, Figure 52.)

We are all used to words. Working with typography and large blocks of type is governed by several guidelines to make the text more readable and legible. Charles Ricketts (1866 – 1931) was a versatile English artist, illustrator, author and printer, and is best known for his work as book designer and typographer from 1896 to 1904. In his publication A Defense of the Revival of Printing (1978) he discusses the position of the printed matter on the page, stating ‘the inner margin the narrowest, the top somewhat wider, the outside (fore-edge) wider still and the bottom widest of all.’ 85 Amongst other factors that make typography legible and readable are explained by Morison, from a working knowledge:

First, it is certain that eyes cannot read with ease any considerable numbers of words composed of letters embodying sharp contrasted thicks and thins; secondly, it is none the less certain that the eye cannot agreeably read a mass of words composed even in a rightly constructed letter, if the lines are beyond a certain length. The most expert reader’s eye cannot seize more than a certain number of words in a given size except in a proportionate length of line. Thirdly, practice proves that the size of the letter must be relative to the length of the line. Respect

---

85 Charles Ricketts, A Defense of the Revival of Printing (Printed at the Ballantyne Press, 1899), 23.
for these principles will generally protect the reader from the risk of ‘doubling’ (reading the same line twice).

Traditional information and application about good typographical practices all help to improve legibility: ‘the aim of art is to make a useful thing beautiful; tradition not only teaches the best way that has been found to do it.’ If a person has a readable typeface to begin with and the layout is not formatted with good practice the end result could be an unreadable body of text. Graphic designers ply their trade with knowledge of typographic principles or guidelines and experience. Graphic designer Paul Felton outlines his version of typographic conventions in his book *Type Heresy, Breaking the Ten Commandants of Typography* (2006):

The first thing one learns about typography and type design is that there are many rules and maxims that enlighten the neophyte. The second is that such rules are made to be broken. And the third is that ‘breaking the rules’ has always been just another one of the rules. …In the history of typography, very little of what has been produced follows the rules, but this may change as many of the rules will be incorporated into our software.

In the light of what was said tradition plays an important part of typography, and thus in legibility and readability, and tradition gives guidance on how to make continuous type an easy read, and giving the reading public what they will read and want to read. Benjamin Sherbow in his 1961 publication *Making Type Work* demonstrated by layout and formatting text in different ways on how best to make typography work. As stated by Bror Zachrisson: ‘The *readability* has to do with how easy, difficult, interesting, or accessible its contents are, relative to the reader. When typography and other physical aspects are concerned, one speaks of *legibility*.’ To achieve both legibility and readability traditional knowledge allows the typographer to make several assumptions.

Since there is always more than one good way of arranging any given piece of text ‘typographic principles’ or typographic guidelines are used, bent and broken to show ‘how much more effective some type arrangement are than other’. The following is an example of the arrangement of different leading. The original Line Spacing diagrams from Sherbow in his 1916 publication *Making Type Work* can be seen in Appendix Two, figure 53.

---

This type is set in Times 12pt, single line spacing. The extract comes from Benjamin Sherbow’s publication Making Type Work printed in 1916, page 95. “Why does your eye find this paragraph less inviting than those that follow? Isn’t it because those below look easier to read? They are. The lines you are now reading are set solid. There is no space between these lines except that provided by the shoulder of the type itself. And that is not enough for a type like this.”

This type is set in Times 12pt, 1.5 line spacing. The extract comes from Benjamin Sherbow’s publication Making Type Work printed in 1916, page 95. “There is no fixed rules about the proper amount of space to place between lines. It depends on the type face and the size you are using. Less leading for small type; more leading for large types. More leading for black-face type than for those of lighter faces.”

This type is set in Times 12pt, double line spacing. The extract comes from Benjamin Sherbow’s publication Making Type Work printed in 1916, page 88. “Spacing is probably the most difficult problem in type arrangement. It is the last thing anyone ever learns to do well. Every piece of type composition has its peculiar problems to be worked out and I cannot hope to tell you how to solve them all. I will try only to indicate the purpose of spacing and how its right use helps to get attention for advertising print, make it easy-to-read and easy to understand.”

Figure 18: Shows 12pt Times top paragraph set solid, second paragraph is set in 1.5 line spacing (18 point leading) and the third paragraph is set in double line spacing (24 point leading). This is an example where the amount of leading are enforced by software in this case Microsoft Word leading options. The texts in the graphic are excerpts from Benjamin Sherbow Making Type Work published in 1916 pages 88 and 95. (Scan of original in Appendix Two, figure 53)

Where no allowance or room is made to move or break the conventions in typography badly formatted typography may result. This is why variables are necessary in typography. Microsoft Word has fixed line spacing restricting the ability to alter the leading for different typefaces to achieve legible typography. Benjamin Sherbow once stated ‘enough space should be put between lines to make them inviting and easy to read. Stop when this has been done—don’t overdo.’ The following was suggested as a guide for leading as some typefaces require more leading than others. An example of where different leadings are required for a typeface of the same point size: ‘Caslon Old Face which, because of its shoulders and long descenders, require less spacing than Bodoni.’

92 Ibid., p14.
Knuth when discussing line breaks with his software states: ‘It is comforting at times to know that the machine needs your help’. This is especially relevant when working with line and word breaks in typographical layout to achieve a good aesthetical typography piece. Bad word breaks (hyphenation) can look bad and disrupt reading and render the text not very easy to read.

In most of the research done by Jean Anisson as far back as 1790, and more recent research conducted by the Software Usability Research laboratory Wichita State University, into typography has produced very restricted criteria. Ruari McLean points out that typefaces should only be checked for legibility in the context of what they were designed for and if they are used for that purpose:

To appraise the legibility of anything, …we must know its purpose. A typeface intended for use in books printed in English can properly be appraised only when so used. A display face intended for magazine advertising has an entirely different purpose; its user may want it to be more ‘noticeable’ than legible.

If research is only on one aspect of typography it will not give a full picture: ‘readability has to do with how easy, difficult, interesting, or accessible its contents are, relative to the reader. When typography and other physical aspects are concerned, one speaks of legibility.’ Legibility and readability are dependent on several aspects not just one aspect. Barbara E. Roethlein in 1912 carried out an investigation at Clark University on ‘the relative legibility of different faces of printing type’ but as Frederic W. Goudy observed that the typefaces investigated were not testing the right typeface for the right use:

The tests were by distance, and type of 10-point size were used, but, with one or two exceptions, of the twenty-six different faces studied none were such as would be selected for printing fine books, not one presenting any aesthetic quality or even approximating an ideal face.

---

94 Donald E. Knuth, *Digital Typography* (CSLI Publications: Stanford, California, 1999), 91.
Research into legibility should be done with specific typefaces and for specific uses. As indicated by Goudy, the typefaces used in the 1912 research would not have been used for fine book production. C.Y. Suen and M.K. Komoda also examined Letter Gothic, Courier and DECwriter typefaces in their experiments to investigate the effect of type style on legibility and on reading proficiency. Yet, with the advancement of technology, reading complete books on screen, for example, on the iPad, Letter Gothic, Courier and DECwriter typefaces would like Roethlein report that not all would be used to produce books for screen use (not the right type). McLean also points out:

Research in legibility, even when carried out under the most ‘scientific’ conditions has not yet come up with anything fundamental that typographic designers did not already know – or believe – with their inherited experience of five hundred years of printing history and their specialized observations of the civilization in which they live.98

As stated by Goudy: ‘Tradition not only teaches the best way that has been found to do it, but shows also the metes and bounds of man’s endeavor reached at the moment, the walled boundaries within which the imagination of the craftsman may have full sway.’99

These boundaries are all part of the knowledge on typography, and are included in typographic design and layout, which produces the typographical material that people read and want to read. The working knowledge of typography leads to revealing research relevant to specific typefaces designed and used for a specific purpose, and should be checked under the conditions they were designed for and also legibility, and for that reason:

The findings of most ‘laboratory’ tests of legibility prove, if they prove anything, what suited those people, of that age and sex, at that time of day (tired? well fed? hungry? in good or bad temper?), in that month, in those conditions. But every job a typographer tackles is in a different set of conditions, and his skill is first to find out what those conditions are, and then to design particularly for them. The designer must always ask ‘what, why, who, when and where?’100

Research into typography together with Roethlein 1912 and the Zachrisson 1965 started with type that was designed for print. The Wichita State University used type designed for both print and screen such as Matthew Carter’s Verdana and Georgia. Matthew Carter is a British type designer who trained as a punch-cutter at Enschedé by Paul Rädisch. In 1997 he was awarded the TDC medal — an award from the Type Directors Club presented to those who have made significant contributions to the life, art, and craft of typography. In 2010, he won a MacArthur Fellowship based on his ‘exceptional

creativity, as demonstrated through a track record of significant achievement, and manifest promise for important future advances. The Verdana family started in early summer 1994 as a two typeface (with Tahoma), designed by Matthew Carter and hinted by Tom Rickner, as a system typeface for Windows 95. Georgia designed by Matthew Carter as a serif alternative to the typeface Times for the nascent Microsoft Network. Both Georgia and Verdana are very carefully spaced so that the characters never touch, and this helps to make them especially readable. In Verdana and Georgia the lower-case letters are about two-thirds the height of the upper-case letters this allows larger counter spaces, this is another factor which adds to their readability. The Georgia and Verdana typeface families were originally commissioned by Microsoft to address the challenges of on-screen display.

Each family features large x-heights, open counters, high contrast between the regular & bold weights, ample spacing, and designs that help distinguish commonly confused letterforms. The fonts were programmed with extensive TrueType hints for improved rendering at small and large sizes in Microsoft Windows, and were developed with support for the WGL Pan-European character set.

Sample of Verdana Regular
(i) curve top and curve end of capital "C" extending beyond baseline and Cap height
(ii) curve top and curve end of lower case "a" and "b" extending beyond baseline and x height
(iii) Showing x height as three quarters the height of the Cap height

Figure 19: Verdana characters showing the large x height and open counters spaces.
Carter designed these typefaces using a working knowledge of typographic design together with the traditional working knowledge. Stanley Morison (1955) described text as not being ‘jolly’, by not drawing attention to itself but letting the characters form words to be read. Edward Johnston (1906) ‘having the distinguishing characteristics of each letter strongly marked’ so there would not be any misreading. Ilene Strizver (2006) who writes and teaches extensively on typography was the creative and production director of *Upper & lowercase* (*U&lc*) and director of typeface development at International Typeface Corporation (ITC) in New York, where she developed more than 300 text and display typefaces with respected type designers as Summer Stone, Erik Spiekermann. In her article in *U&lc* 40.1.2, *What makes a Good Typeface Part 1 of 2* Strizver outlines the ‘factors which affect legibility include weight, character shapes, ascender and descender length, size of counters, stroke contrast, and character width’.  

The factors of legibility are well known in the print and publishing industries, but not so much outside in the general public even though this knowledge has been around since Gutenberg, and is utilised in text everyday:

Three Aspects of Legibility … A long-standing typographic maxim is that the most legible typefaces are “transparent” to the reader—that is, they don’t call undue attention to themselves. Additionally, the most legible typefaces contain big features and have restrained design characteristics. While this may seem like a typographic oxymoron, it’s not. “Big features” refers to things such as large, open counters, ample lowercase x-heights, and character shapes that are obvious and  

---

103 [http://www.itcfonts.com/Ulc/4012/GoodTextFace.htm](http://www.itcfonts.com/Ulc/4012/GoodTextFace.htm) (U&lc Online Issue: 40.1.2)
easy to recognize. The most legible typefaces are also restrained. They are not excessively light or bold, weight changes within character strokes are subtle, and serifs, if the face has them, do not call attention to themselves.

Counters, the white space within letters such as ‘o,’ ‘e,’ ‘c,’ etc., help to define a character. Typographers believe that large counters are an aid to character recognition. A by-product of open counters is usually a large lowercase x-height. As long as the x-height is not excessively large, this can also improve legibility in a typeface. Because over 95% of the letters we read are lowercase, larger letter proportions usually result in a more legible typeface.104

These aspects of legibility again identify elements that can be included when designing text to give legibility on a computer screen.

For over a half a century, Hermann Zapf has influenced developments in typographic design. In fact he is internationally known for his type design. He is also a calligrapher, book designer, teacher and has written many articles about modern technical developments in the art of composition and printing. The following is the commandment number nine of The Ten Commandments of Photo-Typesetting, as written by Zapf in 1982:

Thy mission is, for the most part, to create a harmony between the reader and the printed page; to assist the eye, to smooth the path, and thus advance the role of the visual word. Put aside the temptation to be an exhibitionist, for the honored letters which endow thy craft are thine to use we trust.105

Here again Zapf echoes the fact that typography should be read and not stand out and allowing an even flow of text so to make it readable, and the same goes for a block of text and body copy text (for example a book). Strizver in her publication Type Rules! observed that:

Not all typefaces are designed to be legible. This is more of a consideration for the text designs where the degree of legibility relates directly to holding the reader’s attention for the duration of the copy. Display designs are generally used for a few words in larger settings where the objective is to be instantly noticeable and to convey a mood or a feeling. So legibility might no be as important.106

All typography does not have to be legible. As indicated above, some type designed for display may not be designed to be legible. The smaller the typeface and the larger the quantity of text to be read the more legibility comes into play. Familiarity with a certain typeface and layout of type aid in its readability, ‘You read best, what you read most’. Yet as the completed research over the years demonstrated there are on-going problems with both readability and legibility, for example, readability can be affected by the clever layout of text.

104 http://www.fonts.com/aboutfonts/articles/typography/legibility.htm
105 Hermann Zapf, Hermann Zapf and his Design Philosophy (Society of Typographic Art Chicago, 1987), 234.
106 Ilene Strizver, Type Rules! the designer’s guide to professional typography. 2nd ed. (San Francisco: Bedford Arts, New Jersey: John Wiley & Sons, Inc., 2006), 59.
Figure 21: Shows some display typeface set in 12pt. A full page of this style of these typefaces set for continuous text would not be an easy read.

Sandra Wright Sutherland’s doctoral research deals with the work of Miles Albert Tinker. In her essay ‘The forgotten research of Miles Albert Tinker’ published in the *Journal of Visual Literacy*, volume 9, no 1, 1989, she outlines the background of Miles Albert Tinker (covered in Chapter 3) and makes available a bibliography of Tinker’s studies. She says: ‘He pursued one of the most extensive inquiries into the effect of typographical factors ever conducted.’ He carried out over fifty studies between 1928 and 1952, these studies were published in the *Journal of Applied Psychology*, and they also covered topics relating to typography. In relation to typography he observed:

Eye movement, influence of: type form, line width, colour of print and background; Typography Studies: comic books, relative legibility of letters, digits and mathematical signs, newspaper body types, simultaneous variation in size of type, width of lines and leading for newspaper type. Children’s needs: typography for children, print for children’s textbooks. Tinker also produced two books co-authored by Donald Paterson (Paterson interests were with the instructional technologist). The books are, 1940 *How to Make Type Readable* (with Donald Paterson Harper Brothers: NY) and 1963 *Legibility of Print* (Iowa State University Press, Ames, Iowa). In his *Legibility of Print* (1963) Tinker gives a comprehensive and elucidating survey of the problems of measuring and evaluating legibility.

All typefaces are designed for a specific use. To satisfy the test of legibility the use for which the typeface was designed is extremely important. The purpose for which the

---


typeface is designed is measured against its use. In other words, the test is the practicality of a typeface. McLean stated:

To appraise the legibility of anything, …we must know its purpose. A typeface intended for use in books printed in English can properly be appraised only when so used. A display face intended for magazine advertising has an entirely different purpose; its user may want it to be more ‘noticeable’ than legible’. 109

Gutenberg one of the earliest masters in print, described his epoch-making invention (movable type) in 1439 as ‘adventure and art’. S. H. Steinberg, a Fellow of the Royal Historical Society reminds us: “‘adventure and art’ has ever since remained the characteristic feature of the printed book.” 110

Conclusion

The arrangement of typography by designers (from scribes in Medieval times to present day designers), and printers (from Gutenberg and the incunabula to present day printing) is the public face of typography, and furnishes the source material for the researcher into legibility and readability. Printers and designers incorporate their knowledge of readability and legibility into typographic contexts. The English language similar to other languages is changing all the time, but the need for legibility and readability remains.

New words are constantly coming into use, and not only new words, but also new pronunciations and even new grammatical forms. At the same time, old words, old forms, and old pronunciations are gradually dropping out of use. 111

These changes affect how and what we read. There are some modifications to the design and style of the characters due to styles and fashion in different periods of history, but overall the characters remain the same. Reading involves the decoding of the characters, and any alteration of these characters will affect the legibility and readability of the characters. As pointed out:

The differences necessary to legibility have been neglected by the makers of phonetic alphabets, in their desire to indicate phonetic similarity by similarity of form. 112

The legibility and readability of text together form the human perception of the phonetic system, i.e. a perception of the alphabet, where text is presented in a certain way from handwritten to printed on stock or displayed on screen in all different formats and sharing one common factor – the human factor. The characters are designed by human

---

beings and for human beings, the layout and design of presentation is dictated by human beings and for human needs. The terms used to describe characters are also human related by the use of such terms as face, neck, shoulders, arms and feet. The human factor is totally engaged with typography, and so accordingly, are the two concepts of legibility and readability. The typographic practitioner be he or she a type designer, layout designer, web designer or printer, all play a major role in the way we perceive legibility and readability and these two aspects determine what the reading public see and read.

‘The readability has to do with how easy, difficult, interesting, or accessible its contents are, relative to the reader. When typography and other physical aspects are concerned, one speaks of legibility.’

In other words legibility is concerned with the visual perception of typeface and layout. The typographic practitioner presents the reading public with the raw material and the finished product for reading. ‘You read best what you read most’. Thus the typographic practitioner has a major effect on what is perceived as legibility and readability, and this is a matter that has to be taken into account in any scientific research into the subject of typography.

Assumptions of legibility and readability grew out of traditional practices by typographers from circa 1450, these assumptions are ‘probably best viewed as a body of knowledge, research and opinion to which designers refer selectively, rather than a subject governed by any single unified theory or categorical law.’ The scientific research was conducted by experimentation in laboratories and proved, rather ironically, that the assumptions of traditional practices were correct.

Just as legibility and readability are linked to reading and writing, and reading and writing are linked to legibility and readability both are based primarily on the traditional assumptions of typographers, and as will later be shown in chapter 3, rather than on the results of scientific research that are based solely on empiricism and experimentation.

---


Chapter 3

Criteria and Methods used in Typographical Readability and Legibility Research

Typography is basically two-dimensional architecture. The harmony of the proportions, the grouping of the lines of type, the balance of contrast and symmetry, the dynamic tension of asymmetrical arrangement, are the means which the typographer may use in a given task so that the text is communicated to the reader in the most articulate form. His invention is restricted only by the technical limitations of the materials and the obligations imposed by the history of style.¹

Introduction

This chapter covers the ‘scientific research’ using type as its source material, though the characters of type were designed mainly by typographers who also applied their professional working knowledge developed and accumulated since the beginning of printing and typography. The ‘scientific research’ is primarily associated with psychologists such as Albert Tinker and James McKeen Cattell, and the ophthalmology research conducted by Louis-Émile Javal.

The new technology and reproduction of typography present the designer with new problems due to changes in the way typography is presented to the reader by computers and tablets. While ‘many excellent typefaces from earlier periods are in most effective use today’² the advances in current technology now present the designer with new problems that differ from those in the past. The modern technical demands of high-speed and rotary presses, machine-made paper, and text on computer devices, have presented typography with different limitations, and these have to satisfy the modern technical demands along with legibility. The thesis research topic involves a historical overview of legibility and readability, and in furtherance of the research topic, this chapter will deal with selected research into reading from printed text as this is really where legibility and readability research and studies in relation to these concepts commenced. Understanding what has been done in the past should also assist in the understanding of legibility in present day typography as type characters remain basically the same. During the eighteenth century the design of the roman types

underwent a radical change resulting in the style known as ‘modern style’, and such type style was also used in the nineteenth century, and indeed, is still the type style used today in newspapers and many books. But typography must still conform to the written and unwritten conventions of layout, comprehension and ‘good written practice’. As was said by Spiekermann and Ginger:

‘Most type is used for business communication of one sort or another, so it has to conform to written and unwritten rules of the corporate world…text set for business has to look fairly serious and go about its purpose in an inconspicuous, well organized way.’

The above quote emphasises ‘the obligations imposed by the history of style’ and typographic traditional. The typographical trade knowledge comes from tradition which ‘not only teaches the best way that has been found to do it, but shows also the metes and bounds of man’s endeavor reached at the moment.’ Scientific research does not follow this typographical tradition or history of style as science believes in facts and proof, though not tradition. Richard Southall Typographic Consultant for Xerox stated:

‘Computer scientists believe that if you can’t measure it, it doesn’t exist. Therefore, it is not enough that we typographers know that legibility exists, we have to be able to prove it.’

The search for information on legibility has led to extensive scientific research into the topic. Pyke, for instance, in 1926 in his publication The Legibility of Print identified some 251 reports into various topics of legibility and readability research from roughly 1825 to 1925. In one of his findings regarding legibility in print he noted that:

A fact eloquent to the fundamental trouble is already before the reader: four times as many writers have measured legibility as have defined it. Three out of every four writers have been attempting to measure something the exact nature of which they have not paused to examine.

The ‘exact nature’ of legibility and readability is what the scientific world wants to prove. But there does not seem to be an exact definitation, and, as was stated, in chapter 2 of this thesis on the topic of legibility and readability it was found that: ‘The readability has to do with how easy, difficult, interesting, or accessible its contents are, relative to the reader. When typography and other physical aspects are concerned, one

---

7 A. F. Johnson, Type Designs, ed 3 (Jarrold and Sons Limited: Norwich, Great Britain, 1966), 54.
speaks of *legibility*. Tradition has contributed to the knowledge of the ‘physical aspects’ of typography, such as type size, leading, spacing, line length, shape of the characters and the x-height and ascenders and descenders. The arrangement of all these physical aspects can and do effect legibility, and as there are so many variables it would be difficult to cover all of them in one or two experiments. ‘If you say ‘that is legible’, you mean only that you can read it: you do not know whether I can.’ So how can there be proof for something that is not a fixed entity.

Research into any of these aspects in isolation aids, supports and indicates what makes a typeface legible in relation to that aspect only, for example, if a typeface is studied for the length of line as in Dearbon’s study in 1906, who concluded that optimum line length was 80mm has nothing to do with the length of line in the columns of a newspaper. Results are less than objective in their conclusion regarding the scientific and empirical data considered as a change to any of the ‘physical aspects’ could distort the results. An extensive list of experiments into legibility, readability and word recognition is found in Appendix One.

As was stated in chapter 2, legibility and readability are two separate and distinct concepts, and not just interchangeable words used when referring to a common subject matter. And thus readability and legibility must be researched individually because each of them rely on different factors. Professor of Psychology George R. Klare identified the three functions of readability as follows:

1. To indicate legibility of either handwritten or typography.
2. To indicate ease of reading due to either the interest-value or the pleasure of writing.
3. To indicate ease of understanding or comprehension due to the style of writing.

However, of the foregoing functions, the third one dealing with ‘comprehension’ found favour with researchers such as Pyke, Tinker and Wheildon. In the 1980s Wheildon in his research was questioned more than once by David Ogilvy owner of *Ogilvy & Mather Worldwide* design agency on whether his research was ‘measuring reading comprehension or merely readability’. He responded by saying that his research method came within George R. Klare’s third function of readability, i.e. ‘to indicate ease of understanding or comprehension due to the style of writing’.

---

Tinker carried out one of the most extensive inquiries into the effect of typographical factors ever conducted. As a result of Tinker’s extensive inquiries into the effect of typographical factors a knowledge of his research and conclusions would give a good indication of what is meant by legibility and readability. Some of the factors he studied were type form (lowercase vs. all caps vs. italics), size of type, length of lines, black typography versus white typography, leading and style of typefaces. From 1928 to 1963 he conducted experiments into legibility and readability of text. His observations, questionnaires and findings were published in 50 papers and two books (see Appendix One for a list of his publications). In 1963, Tinker defined legibility as follows:

Legibility, is concerned with perceiving letters and words, and with the reading of continuous textual material. The shape of letters must be discriminated, the characteristic word forms perceived, and the continuous text read accurately, rapidly, easily, and with understanding…[.]Optimal legibility of print, therefore, is achieved by a typographical arrangement in which shapes of letters and other symbols, characteristic word form, and all other typographical factors such as type size, line width, leading etc., are coordinated to produce comfortable vision and ease and rapid reading and comprehension.\textsuperscript{12}

It appears that legibility for Tinker has to do with the physical appearance of the characters, and with the interaction of the typography with the subject/reader when reading the text. Continuous type is arranged and laid out by designers based on tradition to achieve a legible piece of text for the situation where the text is to be read. The working knowledge of the designer is used to gain the ‘optimal legibility of print’, however not forgetting the human contribution required to produce legibile typography. Both the design of the individual characters and the design of the continuous piece of text have to work in tandem to create legibility, and no one factor can achieve it. It is a combination of several factors such as, shape of letters, shape of words, type size, line width, leading, tracking and kerning, (i.e. altering the spaces between a pair of characters or altering the space across a group or selection of words or characters), that creates legibility.

The extent of objective and subjective experiments carried out by Bror Zachrisson and published in his \textit{Studies in the Legibility of Printed Text} in 1965 go a long way to produce a conclusion on legibility and readability, but they do not give a complete picture as he stated himself that he worked for ten years on typographical research ‘on a modest scale’\textsuperscript{13} at the Graphic Institute in Stockholm. While at the Graphic Institute he investigated some factors important to legibility which were ‘mainly psychological and


pedagogical in nature'.' Zachrisson included his traditional knowledge of typography and because of this knew the restriction of the source materials. The print industry, where printers and designers work with typography on a practical basis, also work on the assumption ‘as long as you print on paper, the choice of typeface is governed first and foremost by the content of the message, than the intended audience, and only lastly by technical constraints.’

Legibility is how a human being reacts to the text and can interact with it, yet the preferred setting for research into the matter seems to be that of the laboratory, and thereby removing the ‘human factor’ as much as possible, or at least restricting the subject and thereby reducing variables. Cattell in 1886, gives an example of this, and explains ‘the subject held his attention as constant as possible and was not disturbed by noise or the presence of others in the room’ and control of this sort needed specific laboratory conditions. Cattell’s experiments were conducted in the psychological laboratory of the University of Leipzig. Positivist experiments like that of Cattell’s rely heavily on experimental and manipulative methods. These methods ensure that there is a distance between the subjective bias of the researcher and the objective reality she or he studies. This generally involves hypothesis generation and testing based on proving or refuting. The laboratory setting makes it easier to ‘control and isolate the many correlating factors that play a role in everyday life’, and because of this Pyke also worked under laboratory conditions. Pyke worked in the Psychological Laboratory at the University of Cambridge under the direction of Mr. F. C. Bartlett, and in 1926 his report was published in the Special Report Series, No. 110 Medical Research Council. The report presented a comprehensive discussion of previous legibility research along with his own experimental work on the relative legibility of typefaces.

Tinker, along with others, who studied legibility and readability found that studies carried out in a natural environment allow for too many uncontrollable variables. In research before 1940 the term ‘legibility’ was applied to the factors affecting ease and speed of reading. ‘But since 1940, certain writers use the word ‘readability’ for this purpose’, that is, the purpose and study of legibility. The research of Matthew Luckiesh and F. K. Moss is a good example of this. They used carefully controlled...
investigations involving diverse visual variables to reveal that the normal rate of reading as an insensitive indicator of readability could be compared to the rate of blinking. Luckiesh was a physicist and the director of General Electric’s Lighting Research Laboratory who undertook research into light and vision as part of the relationship between light and seeing.


By applying Tinker’s 1963 definition to measure the legibility of typefaces several factors (i.e. type size, line width, leading etc.) have to be taken into account as ‘no single method of measurement is adequate for determining the legibility of print in all kinds of typographical setups.’ If one factor only is measured the results might not give a true result as adding in another typographical factor (i.e. contrast of limbs, x-height or letter spacing) could change the overall look of the typography, and the legibility of the typography under research. Measuring a single factor of typography will limit the results into legibility in a very exact situation of type usage, but as legibility depends on more than one factor, as illustrated by Tinker in his definition of legibility, the traditional assumption must also be taken into account and that requires, the ‘right type’ for a job in different situations to achieve different purposes. A typeface taken out of the environment for which it was designed might not perform to its full potential, an example of this is the display type Bold Antigue which is designed to be viewed in large and limited quantities, and not used in continuous text. This typeface was researched by Barbara Roethlein in 1912 at a point size used in continuous reading situations. Scientific or objective studies are extensive in the search for legibility and

---

readability, and these studies are carried out in specific areas or factors, i.e. visibility measurement; distance method; the short-exposure method; the focal variator method; rate of involuntary blinking method; reliability and validity of measurement; speed of reading method; measurement of eye movements; length of work period.

**Printed text**

**Factors used to study typography in legibility and readability**

The research outlined in this chapter is grouped under the factors used to study typography in legibility and readability, and these include: visibility measurement; distance method; the short-exposure method; the focal variator method; rate of involuntary blinking method; reliability and validity of measurement; speed of reading method; measurement of eye movements; length of work period. Pyke, in his 1926 survey, divided the criteria of legibility into three categories and termed them objective, subjective and functional. ‘An objective criterion implies a conception of legibility which is restricted to the essentially physical aspects.’ Objective criteria were used to measure certain dimensions and/or ratio of dimensions of the printing symbol and this included size of letters ‘legibility coefficient’ and ‘specific legibility’.

‘The subjective class measures not by any typographical unit, but by some mental or physical state which can also normally be produced by other than typographical stimuli.’ Subjective criteria measured certain passive states of a person reading and these included: fatigue, eye-strain, aesthetic satisfaction (i.e., does the subject like or dislike a typeface and this could be that the subject is acquainted with the typeface or not ‘you read best what you read most’), and judgement of the trained human eye. Pyke in his 1926 report also stated: ‘In my opinion a type can most properly be tested for legibility by actually being read’. ‘Functional criteria’ are methods where the activities and performances carried out either consciously or unconsciously by a person when reading are recorded, and these include distance threshold, illumination threshold, focus threshold, speed of reading, errors, width of eye span (i.e. the visual angle subtended by the group of letters which can be appreciated in one eye-pause’ or duration of eye-pause, number of eye pauses per line, number of eye-refixations ‘i.e. the

fixation by the eye of a point a second time to correct an error in the first fixation, a return movement is involved’, regularity of eye-movement and reading rhythm.\textsuperscript{26} The functional criteria can be affected by the human factor that of fatigue and other human states and emotions such as if the subject is tired, hungry or distracted.

Because of the different criteria used for measuring legibility and readability, the experiments relating to such matters are grouped under different methods as opposed to by date, for example, in the study of eye movement and legibility the research of Louis-Émile Javal in the 1800s, Karl Ewald Konstantin Hering 1879, Lamare in the 1800s, Luckiesh and Moss in 1935 are outlined together. The list of research, experiments and papers on the subject of legibility and readability in the Appendix One appear under two headings, the first being legibility studies and the second readability studies. The research is then listed by date to illustrate a time line on the research and experiments. Where a researcher produced a series of papers over a large period of time these papers are listed together. Eye movement was amongst the first factor to be researched.

**Research with eye-movement and legibility**

In the search for readability and legibility the understanding on how the eye moves and ‘sees’ resulted in the ‘saccade’ being discovered or identified. This factor is still used to aid in the research of legibility and readability. One of the first experiments into reading was by eye-movement around the 1800s resulting in the discovery of ‘saccade’ to refer to rapid eye movement. Saccade is a French word meaning ‘jerk’ or ‘twitch’.

Louis-Émile Javal wrote a series of papers on the visual processes involved in reading (Javal, 1878a, b, c, 1879a, b, c, d, e). He is now widely credited as being the first writer to use the term ‘saccades’ to refer to rapid eye movements.\textsuperscript{27}

Karl Ewald Konstantin Hering (August 5, 1834 – January 26, 1918) was a German physiologist and professor at Charles University in Prague, who researched colour vision and spatial perception. Hering in 1879 was one of the first to identify the ‘sound’ of muscular movement in the eye. He believed that the sound was a consequence of muscle contractions, and he confirmed this by carrying out a series of experimental observations. These experiments consisted of attaching a rubber tube to a cigar holder and listening to the sound produced when it was placed on the eyelids. He compared after-image movement to the sound of the muscular movement, and he also applied this technique to reading. He asked, as cited by Wade and Tatler, ‘Did Javal measure eye


movement during reading?': ‘One can observe the clapping sounds very clearly during reading. Although the eye appears to glide steadily along the line, the clapping sounds disclose the jerking movement of the eyeball’\textsuperscript{28}. This fact was reported by Hering in Über Muskelgeräusche des Auges. Sitzberichte der kaiserlichen Akademie der Wissenschaften in Wien. Mathematisch-naturwissenschaftliche Klasse, 79, 137-154. The recording and linking of the sounds with eye movement came from Hueter in 1878 who made a passing observation that sound could be heard when a rubber tube was applied close to the eyelid. Hueter suggested that the sound was generated by blood flow through the capillaries in the lid.\textsuperscript{29} The identifying of the sound and linking the sound to the movement of the eye ‘saccade’ which to this present day is a principle of word recognition as researched by Kevin Larson of Advanced Reading Technology, Microsoft Corporation.

Other experiments carried out into eye movements were by M. Lamare in the laboratory of Louis-Émile Javal at the University of Paris, and were reported in passing by Javal in 1879 who introduced it to the world as a finding in his laboratory. These experiments was published by Lamare over a decade later in 1892, and the credit for this discovery was later assigned to Lamare by Javal in 1905, as cited by Wade and Tatler: ‘In an important work conducted by M. Lamare in my laboratory, he demonstrated that the horizontal movements of the eye during reading are by no means continuous, but proceed by saccades’. Lamare used several methods in his experiments. The first method was based on counting the number of letters he could read in one minute, and divided that number by the estimated number of pauses made, and the result was ten letter per saccade. The next experiment was to determine the extent of letter recognition during the fixation period. The third method involved counting the number of distinct movements the eye made along a line, and by using this method he discovered discontinuous eye movement by observation, and also by placing a finger over a closed eye when reading with the open eye. To back up his third method finding by observation and touch, Lamare constructed an apparatus that could record the movements and pauses of the eye. This apparatus was similar to the one used by Hering in 1879. Wade and Tatler (quoting Lamare’s 1892 publication) refer to Lamare’s findings with different reading distance from 0.03m to 1m to compare the number of fixation: 'Regardless of distance at which one reads from the same text, the number of


\textsuperscript{29} Ibid., N. J. Wade & B. W. Tatler, (2009).
letters per section does not vary. The findings of Hering and Lamare formed the basis for further research into typography and eye movement, for instance, Tinker’s 1936 publication ‘Readability and Validity of Eye-Movement measured in Reading’.

Javal in the 1800s in one of his experiments covered first the upper half, then the lower half of a line of words, and found that whereas it was often quite impossible to read the text when the upper half was covered, it was comparatively easy to read it when the lower half was invisible. This led to suggestions regarding the construction of letter forms, for example, a shortening of the descenders so that the part around the x-height and the baseline of the characters was the most recognisable. It may be added that Javal’s observations regarding the top half of type being more identifiable than the lower half of type was always a traditional assumed made by typographers and graphic designers. The following graphic illustrates this traditional assumption by graphic designers that the upper part of characters is more identifiable than the lower half of type characters.

Jurisprudence

The top graphic shows the word with the top half covered, and the second graphic shows the bottom half of the characters covered.

Figure 23: The upper half of letters play a major role in deciphering.

Both of the graphics consist of the word ‘jurisprudence’ and it is easier to make out the word from seeing the top half of the word than the lower half alone. This is for upper and lower case text and if the text was set in all caps ‘it can be said that text set in uppercase letters is less legible only because of less variance in character shape, and therefore less distinctive single characters, positive and negative shapes and character forms’. This lends substance to Javal’s experiment and it indicates the more recognisable section of characters by illustrating that in lower case letters the main part of the characters are half way up and above the x-height (x-height is the height of the

---

lower case character without ascenders and descenders), and below this the characters need more detail, to be identified. In the second graphic the sixth character is the letter ‘p’ but from what is shown it could also be an ‘a’.

As was already stated Javal wrote a series of papers on the visual processes involved in reading (see Appendix One) and called them ‘saccades’, and these are still in use today in relation to eye movement. Zachrisson in 1965 cites Javal in relation to his finding that by covering the first the upper and then the lower half of a line of words that ‘it was often quiet impossible to read the text when the upper half was covered, it was comparatively easy to read it when the lower half was invisible.’33 ‘The “New” New Typography – Legibility, a critical view of the state of typography’ an article which states that with the advances of technology ‘It seems that the old theories and ‘rules’ concerning legibility are outdated yet the graphic on the page has the word legibility with the lower half of the word covered and the word is still legible.’34

‘Zapf expressed the hope that letterpress printing be kept alive, for he feels that only metal type can provide a standard of comparison and a true connection with our great typographic heritage… He does not recommend the transfer of existing alphabets into low-resolution systems, for the compromises will be too apparent; rather, he urged, let the new systems provide fresh opportunities for young designers.’35

Hermann Zapf stated in the late 1980s that ‘the new systems provide fresh opportunities’ and these opportunities are found in the legibility of characters on the new technology, and that this was in the infancy of the new technology. Despite the advances in technology the rules or conventions applicable to working with typefaces and typography still apply, but with the changing and availability of software and hardware new principles may be necessary but ‘legibility with the lower half of the word covered and the word is still legible’ still applies as illustrated in the above graphic. The research into eye movement and the way the eye ‘sees’ is still relevant to all reading and legible research. The eye and what the eye can see has been a major source of research into legibility and readability by optimologists by using the visibility method.

33 Bror Zachrisson, Studies in the Legibility of Printed Type (Sweden, Uppsala: Almqvist & Wiksells Boktryckeri AB, 1965), 28.
35 Bigelow, Charles, Paul Hayden Duensing, and Linnea Gentry, eds. (Fine Print on Type, The Best of Fine Print Magazine on Type and Typography. San Francisco: Fine Print & Bedford Arts, 1989, Sandra Kirshenbaum – ‘Bitwitched, Bothered, and Bewildered’), 133
**The visibility method**

A method known as the ‘visibility method’ is associated with the research of M. Luckiesh and F. K. Moss which led to the invention of the Luckiesh-Moss Visibility Meter in 1935, and whose findings were published in the *Sight-Saving Review*, no. 5 (December 1935), pp.272-80 bearing the title ‘The Relative Visibility of Print in Terms of Illumination Intensity’. The Luckiesh-Moss Visibility Meter consisted of two photographic filters with precise circular gradients of varying density, these filters can be rotated simultaneously in front of the eyes while performing a visual task, so an object seen through them is just barely discernible. The apparatus is positioned in front of the eyes in the same position that eyeglasses are worn. The illumination intensity of type was examined and resulted in the following findings:

About $3\frac{1}{2}$ times as much illumination was required to make 6-point Bodoni type as visible as 12 point. Deficiencies in type size between 6 and 12 point can be compensated for by increases in illumination.\(^{36}\)

M. Luckiesh and F. K. Moss findings relate to the amount of space required around each character for the character and words to be identified and read, the smaller the point size the more space is needed around it so it will not overlap and get confused with its neighbouring character or characters, and putting enough space on the type helps to make typography legible, and the space gives the characters illumination with the light colour of a page against the dark colour of type illuminates the characters sets the characters apart. So ‘$3\frac{1}{2}$ times as much illumination was required to make 6-point Bodoni type as visible as 12 point’ and is the same as having good space around the characters. Good spacing have always been put into practice by typographers, and that this is an example of a practice that is understood to improve readability by typographers but before the Luckiesh and Moss experiment there was no scientific proof confirming it. In 1982 Hermann Zapf wrote ‘The Ten Commandments of Photo-Typesetting’ in his commandment VI, he states:

> Thou shalt space thy lowercase letters in a discreet and neighborly manner, encouraging the occasional handclasp of outstretched arms, but loathing the intimacy of touching bodies. Deprive not thy caps and small caps of space in which to breathe lest their beauty fade upon the printed page.\(^{37}\)

This finding which is good practice amongst typographers — the smaller the type the more clear the background so the text can be made out or read and the larger the type the more ‘white space’ there will be around, between and part of the characters, thus making the characters of type easier to distinguish when the type is smaller; the contrast

---


between background and text has to be emphasised so the characters can be read. Part of the white space is leading, and each typeface should be treated as an individual. This aspect was referred to in Chapter 2 and where Benjamin Sherbow was cited as stating ‘enough space should be put between lines to make them inviting and easy to read. Stop when this has been done—don’t overdo.’\textsuperscript{38} Too little or too much white space can effect the readability of continuous text, too little leading can cause ‘doubling, that is, of reading the beginning of the same line twice over’\textsuperscript{39} will occur as a result, and too much leading can make type hard to read. The visibility method studies only a narrow set of ‘physical aspects’ of legibility and does not give a complete picture. Another aspect of legibility and the eye is studied under the distance method, which has been studied by such researchers as E. C. Sanford in 1888, Barbara Elizabeth Roethlein in 1912 and Miles Albert Tinker in 1930.

The distance method

Another method known as the ‘distance method’ was used in determining visibility or perceptibility at a distance of isolated symbols, and symbols used in groups and in words. This method was used by researchers such as E. C. Sanford in 1888, Barbara Elizabeth Roethlein in 1912 and by Miles Albert Tinker in 1930. Before Sanford carried out his study Jean Anisson in 1790s compared the typefaces Garamond and Didot as outlined in Jean François Sobry in his \textit{Discours sur l’art de l’imprimerie} (1799), which was translated by Paul Bloomfield and discussed by D. B. Updike in 1928. Sobry gives the account of Anisson who ‘disliked the new Didot design, was apparently motivated by a desire to prove that Garamond type was more legible’.\textsuperscript{40} Anisson’s experiment showed that a page set in Garamond could be read from farther away than a page set in Didot type of the same size. In the publication \textit{Discours sur l’art de l’imprimerie} Sobry added that: ‘Garamond was careful to emphasise those parts of the shape of his type which distinguish them from one another.’\textsuperscript{41} A typeface that has distinguishing factors in its design, for instance, an ‘a’ not looking like a ‘o’, aids in the ease of recognising each character, and thus makes a typeface more legible over another character in a set situation. Both Didot and Garamond were designed for the same job usage that consists of continuous text. As Anisson used the right type in the right place, set in the same size, thus showing that Garamond had an advantage in reading at a distance over Didot,

\textsuperscript{38} Margenthaler Linotype Company. \textit{The Readability of Type} (Brooklyn, New York: Margenthaler Linotype Company, 1947), 14.
\textsuperscript{40} G. Thomas Tanselle, \textit{Bibliographical Analysis, A Historical Introduction} (United Kingdom: Cambridge University Press, 2009), 110.
\textsuperscript{41} Ibid., p110.
so Anisson results should be acknowledged and not dismissed as they come from a practical point of view by taking the human factor into account.

The distance method required the characters to be read and positioned at different distances from the reader/subject. This was done by an apparatus consisting of a rail about 3 meters long placed before the subject who was in a sitting position with a headrest fixed at the upper end of the rail. The headrest ensured the position of the subject. A centimetre scale was fastened to the edge of the rail. The letters, digits or words to be investigated were placed in a small well-illuminated car which was capable of movement to the desired distance along the rail.

Sanford in 1888 used the distance method to examine ‘The Relative Legibility of the Small Letters’, published in the *American Journal of Psychology*, 1 (May, 1888), pp. 402-35, where he stated that:

> It can be said a priori that legibility will be favored by enlarging the size and increasing the difference of the letters. And it is easy to show also that legibility is favored by simplicity of outline and concentration of the differentiations upon one particular.\(^{42}\)

The following is a description of Sandford’s findings and experiments. Sanford found that the orders of legibility differed and produced different results depending on the method used and he used three methods, i.e. two types of distance method and one time exposure method. Legibility for distance was measured in two ways with five subjects. In the first method the letter-disk (a device to display each character) was set at fixed distances, and the complete alphabet was shown twice or more at each distance. The second method was intended to be a check on the first method, and also to fix the accurately the distance at which the letters are ‘just’ legible. The second distance method position the character in the letter-disk at the bottom of the rail and then the letter-disk moved up the rail and when the letter became identifiable the position was recorded. The results of each distance method were different thus showing that only using one factor or method will not give a definite answer on the legibility of characters. The results of the Sanford experiments with the typeface Snellen show that there are three groups of different legibility: left group — good; middle group — fair; and right group — poor (‘order of distance’ was a result of the combination of distance method one and distance method two).

By knowing which characters have poor legibility, and comparing them with the characters that have good legibility, a trend/pattern can be found and pattern along with the characters that are misread for others characters narrows down the problem of legibility. However this does not make text more readable as readability depends on the phonetic alphabet and the way human beings speak as stated ‘the readability has to do with how easy, difficult, interesting, or accessible its contents are, relative to the reader’ and not just identifying each separate character to understanding the combination of word. It seems that this research produced another piece into the puzzle that is legibility, but only produced proof on one aspect of legibility and not a complete picture. Research following on from Sanford’s research contributed to this finding. One such research was that of Barbara Elisabeth Roethlein in 1912. The aim of Roethlein’s research was to determine the relative ease or difficulty with which various typefaces of printed letters are read, and to discover what relationship exists between legibility and certain definite modifications of typefaces. The following is an account of Roethlein research and the typefaces that were studied and an in-depth description of the ‘distance method’.

The following is a description of Roethlein’s research that involved the relative legibility of different faces of printing types. She used a technique limited to the specific situation that of a certain size character with a certain number of typefaces for the legibility of isolated characters and groups of characters. The mechanism used was similar to that used in the distance research of Sanford. When demonstrating her method she used sheets of printed type from the list shown in Figure 24. These typefaces consisted of some thirty roman typefaces together with italic, bold, condensed and expanded. The apparatus consisted of a mechanism whereby these letters could be presented at a variable distance from the observer. The bench was 440 cm long, 15 cm wide. At one end of the bench there was a headrest to aid the observer to maintain and assume a constant position in relation to the observed characters. This device had a carriage that consisted of an illuminated box held sheets of printed characters. Each sheet contained twenty-eight letters of the same typeface and case with two of the letters repeated. The characters were in random sequence set in four lines with a letter-spacing

of 37 cm apart and on adjacent lines. The characters were set in 10 point (10pt). All the reading was carried out in an artificially lit room so that the illumination of the room could be controlled. After the reader had become accustomed to the illumination of the room the sheets of the letters were mounted on the carriage on the bench. The reader was also positioned on the bench a set distance from the carriage with the illuminated characters,

![Figure 24: Typefaces used in Barbara Elisabeth Roethlein research ‘The relative legibility of different faces of printing type’. Source: http://archive.org/stream/relativelegibility00roetrich#page/n23/mode/2up](http://archive.org/stream/relativelegibility00roetrich#page/n23/mode/2up)


---

and was then instructed to read the characters at a uniformed tempo, substituting ‘blank’ for the name of the letter that was not easily decipherable. After each reading the carriage was moved to a different position (20 cm nearer the reader’s eye). The process was repeated moving the carriage 20 cm each time till all the characters were identified. The examiner recorded any misreading on sheets of type identical to the sheets in the carriage, and the farthest distance at which each letter was read. Six observers took part in this experiment and each of the fifty-two sheets of letter (for the fifty-two different faces used) were read twice. A period of seven days elapsed between the first and the second reading of any sheet. The sheets were cut longitudinally and their transverse diameters were rearranged to the position of the character before the second reading. The observers gave a complete series of one hundred and four readings and had ‘emmetropic or adequately corrected vision’.

Roethlein’s 1912 research established that confusion can occur between letters next to one another; the research also showed that different combinations of letters produced different results, thus causing misreading in certain letter positions. The results are slightly different from the Sanford study but the Roethlein research contributes to the fact that the orders of legibility differ with the method used, and the characters are the same from A to Z, the style of the characters used are slightly different depending on the typefaces used, so it may be concluded that the variable that gives the difference in order of legibility is the human variable and without humans and reading there would be no need for characters and for the characters to be legible or readable. The following are the categories that can cause misreading in the Roethlein research:

Letters which may be regarded as members of a common category were especially likely to be confused with one another; r, v; o, c, e; x, z; u, n; b, h, k; q, y; i, l, j, t, f; M, W; H, K, E, B, D; O, Q, C, G; V, Y, F, T; I, J, L. Several wholly new types of misreadings made their appearance when the letters were presented in groups. These may be described as 1. Combinations, 2. Separations, and 3, Elisions. 1. It frequently happened that adjoining letters were blended together by the reader, and that a single letter was constituted by this combination of parts, or wholes, of different letters, thus: lc (k); ls (k); lx (k); li (h); cl (d); cf (d); un (m); in (m); vr (w); js (p); vj (y); cj (q); hj (ly); bj (lq); chn (dm); ck (dx). 2. The separation of letters into their parts has been illustrated in the above group. It also occurred in such cases as wm (vun); ld (bl); bj (lq); hj (ly); kd (hel). 3. Perhaps the most striking misreading was due to the complete elision of certain letters of the group.

---

This phenomenon was especially common with such slender or narrow letters as i, j, t, r, v, s. When i or t was interpolated between ascending letters, when j occurred between descenders, and when r and s were present in any context of whatever sort, they were likely to be wholly overlooked. And it frequently happened in such cases that the observer read and reread the group of letters specifying correctly every letter which was present excepting these narrow letters.47

It seems here that this research indicates what affects the recognition of letters and provides some interesting questions for exploration and experimentation and what to take into account when designing a typeface. For example, can the design of the following characters: o, c, e; be modified in any way so they will not be confused with one another? Or how can you modify the shapes of u, n and i so that when in groups of un, in, that there will not be any confusion for m? This question of the shape of characters is relevant for all typefaces no matter if they are the right typefaces for the job they are used for or not. But if the right typeface is used the reader will be more comfortable reading the text and thus not misreading characters as much.

The right type

The right type is a traditional assumption of what typeface is right for a certain job though it is not something that can be defined. Type characters are tools of the designers, typographers and anyone who puts words together on a page be it paper or on screen. Not every tool is fit for every job; there are suitable and unsuitable tools. The same as an ordinary tool ‘the type must express its purpose; a type designed as a newspaper face is unsuitable for a book of lyric poetry as a display advertising face is for a lengthy text.’48 Using the right tool for a job is the same as choosing the right face for the right job. Zachrisson using the traditional assumption of the right type for the right job stated: ‘One of the merits of Pyke’s report is an analysis of the criteria of legibility, especially those factors which influence two of the most frequently used functional criteria, speed of reading and errors.’49 Pyke questioned Roethlein’s technique and her conclusions as to the ‘relative legibility of the twenty-six faces should be accepted only with great reserve’. He particularly questioned ‘the method of illumination, the utterance by observers of the word blank, the most peculiar direction of reading, and the criterion used for isolated letters’.50 The typefaces or tools were not

used as they were designed for ‘the obligations imposed by the history of style’\textsuperscript{51}. The
typefaces chosen would not all have been used for body-copy or continuous textual
material by a typographer based on traditional typographical knowledge: body-copy or
continuous textual material being between 9pt. and 12pt., and also the typefaces chosen
in Roethlein’s research were not all the ‘right type’. The ‘right type’ is one that ‘strikes
a balance between practically and aesthetics — that’s what design is all about.’\textsuperscript{52} The
‘right type’ produced a design with the typeface choice, layout and design which works
to the client’s needs and requirements giving the reader what they want to read and will
read. An example of the ‘wrong type’ for continuous text is Bold Antique or extra bold
typefaces that would not be used for continuous textual material or body copy but for
display. The following graphics illustrate the reason why these typefaces should not be
used for body copy or continuous text, the purpose of book layout is to produce a
readable text ‘with the view to make clear the text’\textsuperscript{53} and an easy read. When the
following graphics are read the bold typeface is not as readable as the roman text
because smaller point sizes are used in body copy or continuous textual material (this is
for an average reader with years of reading and not a child just learning to read) and the
bolder typefaces give the image of being cluttered. The extreme contrast and the
thickening of limbs have been studied and found not to be advisable for continuous text
by such researchers as Hansard in 1825, Javal in 1905 Parsons in 1922 and Morison in
1924. The addition of white space, either letter spacing or leading, would improve the
readability of the graphics, and the typefaces in the graphics can be made work in a
given situation with clever design and layout. In Roethlein’s research all the characters
were presented in the same format, a default format, and some of the typefaces were
designed to be viewed at this size (that is 10pt), thus some typefaces had an advantage
over other giving an unfair playing field between typefaces. Roethlein’s choice of
typefaces let her research down because the typefaces were viewed out of context and
not the ‘right type’ for the job, thus distorting the overall findings in her research. When
typefaces are studied or judged in the situation they are designed for the research can
prove or disprove the success of the typeface for that given task and only for that given
task. The following graphics (figure 25 page 91, figure 26 page 92 and figure 27 page
93) are sample pages set in 9pt on 11pt leading to a page width of 100mm by 170mm
this would be an example of a typical continuous text reading as is found in paperback

books. The following pages are taken from Emily Brontë, Wuthering Heights chapter XIV as reproduced in the Penguin Popular Classics, 1994, first published in 1847.

With the increase in cost of paper and printing those engaged in the production of books take into account, first, what will get communicate the message of the book to the reader, and secondly what is economically viable. So using a typeface to get as many words on the page is the aim of a publisher ‘wily men of commerce’, to produce a book that the reading public will read and want to read, but not at the expense of losing its readability as losing its readability would also mean loss of its legibility: Sherbow stated in 1916 ‘with the view solely to make clear the text’. Janson text allows for a large amount of words per page at this size (9pt) and leading (11pt) and is readable, and this may be described as a ‘right type’ for the job at hand. So this typeface checked for legibility by Roethlein was researched in the right size for the right use. Other typefaces Roethlein researched were typefaces designed for different uses, and this places a question mark over her finding. The question may be asked why should a typeface be studied for continuous reading when that typefaces was designed for a totally different purpose, and would more than likely never be used in continuous textual matter or body-copy. This point was also supported by Hansard’s 1825 paper on the contrast in thickness and thinness of lines in which he declared that he was ‘opposed to extreme contrast’ and it should not be used for continuous text or body copy.

---


Chapter XIV

As soon as I had perused this epistle, I went to the master, and informed him that his sister had arrived at the Heights, and sent me a letter expressing her sorrow for Mrs. Linton's situation, and her ardent desire to see him; with a wish that he would transmit it to her, as early as possible, some token of forgiveness by me.

"Forgiveness!" said Linton. "I have nothing to forgive her, Ellen. You may call at Wuthering Heights this afternoon, if you like, and say that I am not angry; but I'm sorry to have lost her; especially as I can never think she'll be happy. It is out of the question my going to see her, however; we are eternally divided; and should she really wish to oblige me, let her persuade the villain she has married to leave the country."

"And you won't write her a little note, sir?" I asked imploringly.

"No," he answered. "It is needless. My communication with Heathcliff's family shall be as sparing as his with mine. It shall not exist."

Mr. Edgar's coldness depressed me exceedingly; and all the way from the Grange I puzzled my brain how to put more heart into what he said, when I repeated it; and how to soften his refusal of even a few lines to console Isabella. I dare say she has been on the watch for me since morning; I saw her looking through the lattice, as I came up the garden causeway, and I nodded to her; but she drew back, as if afraid of being observed. I entered without knocking. There never was such a dreary, dismal scene as the formerly cheerful house presented! I must confess, that if I had been in the young lady's place, I would, at least, have swept the hearth, and wiped the table with a duster. But she already partook of the prevailing spirit of neglect which encompassed her. Her pretty face was wan and listless; her hair uncured; some locks hanging lankly down, and some carelessly twisted round her head. Probably she had not touched her dress since yester evening. Hindley was not there. Mr. Heathcliff sat at a table, turning over some papers in his pocket-book; but he rose when I appeared, asked me how I did, quite friendly, and offered me a chair. He was the only thing there that seemed decent; and I thought he never looked better. So much had circumstances altered their position, that he would certainly have struck a stranger as a born and bred gentleman: and his wife as a thorough little strumpet! She came forward eagerly to greet me; and held out one hand to take the expected letter. I shook my head. She wouldn't understand the hint, but followed me to a sideboard, where I went to lay my bonnet, and importuned me in whisper to give her directly what I had brought. Heathcliff guessed the meaning of her manoeuvres, and said:

"If you have got anything for Isabella (as no doubt you have, Nelly), give it to her. You needn't make a secret of it! We have no secrets between us."

"Oh, I have nothing," I replied, thinking it best to speak the truth at once. "My master bid me tell his sister that she must not expect either a letter or a visit from him at present. He sends his love, ma'am, and his wishes for your happiness, and his pardon for the grief you have occasioned; but he thinks that after this time, his household and the household here should drop intercommunication, as nothing

Figure 25: Emily Brontë, *Wuthering Heights* chapter XIV as reproduced in the Penguin Popular Classics, 1994, first published in 1847. The type was set in in Janson text 9pt on 11pt leading.
Cheltenham Bold

I would have torn his heart out, and drank his blood! But, till then—
if you don’t believe me, you don’t know me—till then, I would have
died by inches before I touched a single hair of his head!”

“And yet,” I interrupted, “you have no scruples in completely
ruining all hope of her perfect restoration, by thrusting yourself into
her remembrance now, when she has nearly forgotten you, and
involving her in a new tumult of discord and distress.”

“You suppose she has nearly forgotten me? He said. “Oh, Nelly! you
know she has not! You know as well as I do, that for every thought
she spends on Linton, she spends a thousand on me! At a most miser-
able period of my life, I had a notion of summer; but only her own
assurance could make me admit the horrible idea again. And then,
Linton would be nothing, nor Hindley, nor all the dreams that ever I
dreamt. Two words would comprehend my future—dead and hell:
existence, after losing her, would be hell. Yet I was a fool to fancy for
a moment that she valued Edgar Linton’s attachment more than
mine. If he loved with all the powers of his puny being, he couldn’t
love as much in eighty years as I could in a day. And Catherine has a
heart as deep as I have: the sea could be as readily contained in that
horse-trough, as her whole affection be monopolised by him! Tush!
He is scarcely a degree dearer to her than her dog, or her horse. It is
not in him to be loved like me: how can she love in him what he has
not?”

“Catherine and Edgar are as fond of each other as any two people
can be,” cried Isabella, with sudden vivacity. “No one has a right to
talk in that manner, and I won’t hear my brother deprecating in
silence!”

“Your brother is wondrous fond of you too, isn’t he?” observed
Heathcliff scornfully. “He turns you adrift on the world with surpris-
ing alacrity.”

“He is not aware of what I suffer,” she replied. “I didn’t tell him
that.”

“You have been telling him something, then: you have written,
have you?”

“To say that I was married, I did write—you saw the note.”

“And nothing since?”

“No.”

“My young lady is looking sadly the worse for her change of
condition,” I remarked. “Somebody’s love comes short in her case,
obviously: whose, I may guess; but, perhaps, I shouldn’t say.”

“I should guess it was her own,” said Heathcliff. “She degenerates
into a mere slut! She is fired of trying to please me uncommonly
early. You’d hardly credit it, but the very morrow of our wedding,

Figure 26: Emily Brontë. Wuthering Heights chapter XIV as reproduced in the Penguin Popular Classics, 1994,
first published in 1847. The type was set in Cheltenham Bold text 9pt on 11pt leading.
visit from him at present. He sends his love, ma'am, and his wishes for your happiness, and his pardon for the grief you have occasioned; but he thinks that after this time, his household and the household here should drop intercommunication, as nothing could come of keeping it up.

Mrs. Heathcliff's lip quivered slightly, and she returned to her seat in the window. Her husband took his seat on the hearthstone, near me, and began to put questions concerning Catherine. I told him as much as I thought proper of her illness, and he extorted from me, by cross-examination, most of the facts connected with its origin. I blamed her, as she deserved, for bringing it all on herself; and ended by hoping that he would follow Mr. Linton's example and avoid further interference with the family, for good or evil.

"Mrs. Linton is now just recovering," I said; "she'll never be like she was, but her life is soared; and if you really have a regard for her, you'll shun crossing her way again: nay, you'll move out of this country entirely; and that you may not regret it, I'll inform you Catherine Linton is as different now from your old friend Catherine Earnshaw, as that young lady is different from me. Her appearance is changed greatly, her character much more so; and the person who is compelled, of necessity, to be her companion will only sustain his affection hereafter by the remembrance of what she once was, by common humanity, and a sense of duty!"

"That is quite possible," remarked Heathcliff, forcing himself to seem calm: "quite possible that your master should have nothing but common humanity and a sense of duty to fall back upon. But do you imagine that I shall leave Catherine to his duty and humanity? And can you compare my feelings respecting promise from you, that you'll get me an interview with her: consent or refuse, I will see her! What do you say?"

"I say Mr. Heathcliff," I replied, "you must not: you never shall, through my means. Another encounter between you and the master would kill her altogether."

"With your aid, that may be avoided," he continued; "and should there be danger of such an event—should he be the cause of adding a single trouble more to her existence—why, I think I shall be justified in going to extremes! I wish you had sincerity enough to tell me whether Catherine would suffer greatly from his loss: the fear that she would restrain me. And there you see the distinction between our feelings: had he been in my place, and I in his, though I hated him with a hatred that turned my life to gall, I never would have raised a hand against him. The moment her regard ceased, I

Figure 27: Emily Brontë. **Wuthering Heights** chapter XIV as reproduced in the Penguin Popular Classics, 1994, first published in 1847. The type was set in Franklin Gothic Heavy Italic text 9pt on 11pt leading.
Cheltenham Bold and Franklin Gothic were part of Roethlein’s research and have the same extreme thick-and-thinness and uniform thickness that was advised against to achieve legibility by Hansard, Roethlein in her research used extra bold faces: Franklin Gothic and Bold Antique and bold faces: Cheltenham Bold, Clearface Bold and Century O. S. Bold at the size of 10pt which is used for continuous text. Another reason why these typefaces would not be used in a book of continuous text is that a printer would have to use more material to produce a legible book.

Display typefaces ‘demotes a face based around particular associative and decorative values, but also indicates that the face would be impractical for use at small scale or in the setting of continuous text.’ Display typefaces were created for best appearance at large sized (of about 36 or larger) as might be used for a major headline on a book cover or a newspaper. These display typefaces were created with the lack of ‘ink traps’ small indentations at the junctions of letter strokes. In smaller point sizes, these ink traps were intended to fill up when the letterpress were over-inked. Franklin Gothic Extra Bold and Cheltenham are other display typefaces but not designed to be used for a ‘lengthy text’ as it would make for hard continuous reading. From 1948 Herman Zapf designed 175 alphabets for hand composition for the linotype typesetting machine, photocomposition and digital laser systems. The Society of Typographic Art in Chicago when celebrating its 60th anniversary (1987) and in recognition of Zapf’s contribution to typography published *Herman Zapf and His Design Philosophy*. In this publication the right type (the right type is a term used by typographer for picking a typeface that works with the job at hand to get the required message to the target audience) is explained:

Types are tools, the tools of the compositor. There are suitable and unsuitable tools, and not every tool is fit for every job; it is the compositor’s task to choose the right face for the right job. Like a good tool, the type must express its purpose; a type designed as a newspaper face is as unsuitable for a book of lyric poetry as a display advertising is for lengthy text.

In 1930 Tinker used the distance method to examine ‘The Relative Legibility of Modern and Old Style Numbers’ which was published in the *Journal of Experimental Psychology*, 13 (October, 1930), pp. 453-61.

The relative legibility and speed and accuracy of reading modern and Old Style digits in groups and isolation were determined. Old Style digits were somewhat more legible than modern digits in isolation, and Old Style were considerably more legible in groups. Under ordinary reading conditions the two styles of digits were read equally fast and accurately.

---

The distance method for single characters and groups of characters and not continuous text is used only to study the recognisability of type, i.e. to identify characters correctly, and this method was used in the Sanford and Roethlein research. Continuous text is read as a unit and not as individual characters and because of this the distance method has no validity for the investigation of typographical factors such as leading, line length, optimal typefaces or determination of optimal type size for reading continuous text as the characters are presented as individuals and not in continuous text. Tinker stated that this method ‘has been found useful in studies of relative legibility of letters of the alphabet and digits, of specific letters in different typefaces, and the effects of brightness contrast between print and paper.’\textsuperscript{60} The reason for this is as Tinkers states:

Optimal legibility of print, therefore, is achieved by a typographical arrangement in which shapes of letters and other symbols, characteristic word form, and all other typographical factors such as type size, line width, leading etc., are coordinated to produce comfortable vision and ease and rapid reading and comprehension.\textsuperscript{61}

It may be concluded that checking individual characters or group of meaningless characters will give a narrow result, and that the result will only be valid for the legibility of individual characters or group of meaningless characters and not for the same typefaces at the same size for continuous textual material. But in order to correctly assess this you need to sample across all ethnicities and levels and degrees of efficiency with in reading for continuous textual material i.e. a sample could not capture all the contributing factors and the facet of all typefaces. One major contributing factor for checking legibility of continuous text would be meaningful words designed with the ‘right type’ and layed out for the purpose of continuous textual material. Another method the ‘short-exposure’ method was also used to research the legibility of individual characters. It demonstrates how characters can be mis-read for another character thus giving guidance to the type designer on which character needs more attention to make it individual, and one that is not mistook for another character.

\textsuperscript{60} Miles A. Tinker, \textit{Legibility of Print} (Ames, Iowa, U.S.A.: Iowa State University Press, 1963), 11.
\textsuperscript{61} \textit{Ibid.}, p7-8.
The short-exposure method
Sanford’s time test used the short-exposure method. This is where the individual characters are exposed for a short length of time generally between two and six one-thousandths of a second. The short-exposure method was used for the measuring of the relative legibility of letters and digits, specific letters in different typefaces and the effect of variations in brightness contract between paper and print. Line width, leading and determining optical size of type cannot be investigated by the short exposure method so there is no advantage using this method for ordinary reading of continuous textual material. This method measured legibility by determining the speed and the accurate perception of printed symbols. The apparatus that was used for short-exposure was termed a tachistoscope. An example of such a tachistoscope is the Dodge mirror tachistoscope.

The relation between tachistoscopic reading and ordinary reading of continuous textual material is so small that conclusions concerning legibility of continuous printed text from tachistoscopic results must be made with caution. About the only exception to this rule are results for (a) brightness contract between print and paper and (b) small print versus an optimal size.62

The tachistoscope method involves a pre-exposure field, and an exposure field, switching between each at a controlled time interval. The exposure field contains the printed material and a post-exposure field. In some tachistoscopes the post-exposure field and the pre-exposure field are the same. The exposed field is viewed briefly at about 1/10 second or less and this is enough time for a clear view of the print, and also this period of time means that the exposure to the print is shorter than the reaction time of the eye. ‘This arrangement yields a single act of vision, since the timing prevents movement of the eye to a second fixation point.’63 When this method is used to measure the speed of vision the exposure to the print is reduced to accurately identify the symbol. This can be as short as 3 to 5 thousandths of a second of exposure to the symbol.64 The tachistoscope method removes the element of eye movement which was identified by Lamare in his discovery of the saccade, and is directly linked to the movement of the eye while reading or identifying words. The method does not however identify what is legible in continuous text as the method removes the element of eye movement. The tachistoscope is one piece of apparatus used in the search for legibility of individual characters. Another invention was the Focal Variator but again this was used only to identify the legibility of individual characters or single words.

63 Ibid., p12.
64 Ibid., p12-14.
The apparatus described here is a modification of Dodge's mirror tachistoscope. The principal changes made were: (1) An electronic timing-circuit was substituted for Dodge's drop-slide; (2) helium-filled tubes were used for illumination that rectilinear pulses, hence more accurate exposure-times, would be obtained; and (3) the transmitting-reflecting mirror was moved from the periphery to the center of the apparatus.


The Focal Variator

In 1917 A. P. Weiss invented the Focal Variator. The focal variator is a system of lenses arranged to each other to produce a visual stimulus (in the case of typography – printed copy) and is projected upon a ground glass screen with different degrees of clearness from an unrecognisable blur to clear crisp focus, and by doing so the different degree of focal can be measured and recorded. The lenses are interconnected in such a way that they travel in opposite directions: one lense increases the type, the other reduces the size of the type. The focal variator controls the degree to which characters and letters may be thrown out of focus, and so it can be determined when the characters remain
distinguishable. The focal variator was used by Burtt and Basch in comparing the legibility of upper case and lower case individual letters of Bodoni, Baskerville Roman and Cheltenham typefaces. From this research the general order of legibility for both upper case and lower case of the three faces were first Cheltenham, next Baskerville and then Bodoni.

The blurring of a projected image as an index of letter discernibility was first used by Weiss in 1917. The principle of focal variator, the object to be observed, is illuminated and the rays are reflected onto a screen. The distance at which the object is recognisable is measured from a set point, i.e. the point where the observer’s head is held in position. The light and the distance from the object were fixed, the object viewed is blurred, and then viewed, and the point where a word or a letter (blurred object) is correctly named (i.e. when the subject can make out the blurred character) the amount of ‘blurriness’ is recorded. A natural action of the eye is blinking and this was another factor looked in the research in reading.

**The Blink test**

Numerous investigations carried out by M. Luckiesh and F. K. Moss in 1939 and Luckiesh in 1947 promoted blink rate as a measurement of readability. ‘It is assumed that any factor which reduces ease of seeing will increase frequency of involuntary blinking. Conversely, a typographical setup which is read with great ease should produce fewer blinks.’ Zachrisson in 1965 when commenting on the link between blinking and fatigue stated that ‘blinking has been assumed to be a sign of fatigue. This has not been proven. Blinking may be a way of relieving strain, but that is not the same thing.’ Normal blink rate is about 20 blinks per minute, although there are wide variations and this frequency is reduced by as much as 7.5 blinks per minute when you are concentrating on your computer screen and digital typography. Blinking reduces dry eye, the less you blink the more dry your eyes become. Fatigue may be caused by, for instance, by lack of sleep, over work, lack of food or illness. Blinking however does not necessarily prove that one typeface is more legible than another, owing to the presence of many other factors that can effect the results. Luckiesh and Moss’s research used the following method: for a period of five minutes the subject read continuous text printed in sets of different point sizes, for example, text set in 6-point type and 12-point

---

66 Ibid., p270.
67 Ibid., p15.
type, and the eye blinks were counted by direct observation for the test period. Several subjects were tested, and the test was repeated for each subject in different sequences. Conditions were kept constant for all the subjects and the data for the subjects were averaged. In 1948 Tinker carried out an experiment based on eye blinks with the reading of 12-point book type and 7-point newspaper giving each subject two experimental sessions. The subjects’ eye blinks were recorded when reading the 12-point book type and 7-point newspaper with a reversal of the order at the second session. The findings were published in the Journal of Educational Psychology in January 1948. The results showed that 7-point newspaper was easier to read than the 12-point book type. However, the research by Paterson and Tinker in 1942 ‘Influence of Size of Type and Eye Movement’, and the research by Paterson and Tinker in 1946 ‘The Relative Readability of Newspaper and Book Print’ established that the reverse was true. The findings of the blink test by Tinker in 1948 were as follows:

<table>
<thead>
<tr>
<th></th>
<th>Book Type Scores</th>
<th></th>
<th>Newsprint Scores</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st 5 mins</td>
<td>2nd 5 mins</td>
<td>Total 10 mins</td>
<td>1st 5 mins</td>
</tr>
<tr>
<td>Mean</td>
<td>34.28</td>
<td>35.08</td>
<td>69.37</td>
<td>31.77</td>
</tr>
<tr>
<td>S.D.</td>
<td>26.27</td>
<td>29.84</td>
<td>53.65</td>
<td>26.26</td>
</tr>
</tbody>
</table>

Because of a conflict in findings between the 1942, 1946 and 1948 findings Tinker concluded:

It appears that frequency of reflex blinking cannot be accepted as a valid measure of ease of seeing or legibility. At least, the technique is questionable if no experimenters other than Luckiesh and his colleagues are able to duplicate his results…In any case, rate of blinking as a criterion of ease of seeing is in question.  

Ease of seeing relates to readability, but as legibility is concerned with the perceiving of letters and words, seeing the characters is also part of legibility. Due to the fact that there is a conflict in the results, and also the fact that there could have been ‘hidden fatigue’ as a result of another factor by, for instance, the subject getting bored and thus causing a lapse in attention and an increase, or decrease, in blinking.

Zachriss points out that investigation such as Poulton in 1958 using data given by Carmichael & Dearborn got different results ‘shows that there was a consistent and significant increase in the rate of blinking’. The investigation by Tinker (1948) of the legibility of newsprint versus book print the blink rate used as a criterion showed that

---

70 Ibid., p.19.
this method was not valid as a measurement of the ease of seeing. The lack of consistency in the results of the blink experiments, and the fact that there are so many other variables to contribute to ‘hidden fatigue’, has rendered this method questionable when measuring the legibility of characters by itself. But like the distance method experiments involving the blink test can produce information that when used in combination with other methods could give more of a complete result. The blink test has the human element included and this human element produces the inconsistency in the results. The research done to date into legibility has been dominated by the positivist approach to research. The variable element seems to have been excluded or reduced down to almost nothing in the gaining of knowledge from ‘positive’ verification of observable experiments rather than introspection or intuition.

The speed of reading method

In relation to Colin Wheildon research on readability from 1982 to 1990, David Ogilvy more than once posed the question was Wheildon ‘measuring reading comprehension or merely readability’? Readability is the ease with which the eye can absorb the message and move along a sentence, and this is in effect the speed of reading: how fast the text can be read and how well the text is understood how this can also be affected by fatigue and ‘hidden fatigue’. Another factor that makes text readable is the reading ability of the subject, and reading text above that ability and comprehension may also affect the readability of the text. The rate of reading or speed of reading was used by Cohn and Rübencamp in 1903 citing Weber (1881) as having used the rate of reading to determine the effect of letter size on reading continuous text. Weber’s study found that 1.5mm was a suitable x-height with no improvement in speed above 2mm. ‘The reading habit is strong and may form a predisposition towards an adductive movement.’ Speed of reading was used more for checking the comprehension of text and not the legibility of text. The comprehension of text depends on the reading level of the subject and also the understanding of the text by the reader, it does not have an impact on whether a person can identify a character or not. As stated by Tinker the speed of reading depended on comprehension: ‘Perry & Whitlock (1952): Under normal circumstance a reader is limited in speed only by his rate of comprehension. “The reader reads in order

72 Bror Zachrisson, Studies in Legibility of Printed Text (Uppsala Sweden: Almqvist & Wiksells Boktryckeri AB, 1965), 60.
73 Colin Wheildon, Type & Layout: Are you Communicating or Just Making Pretty Shapes? Additional material by Geoffrey Heard and forward by David Ogilvy (Hastings (now Mentone), Australia: The Worsley Press, 2007), 140.
74 Bror Zachrisson, Studies in Legibility of Printed Text (Uppsala Sweden: Almqvist & Wiksells Boktryckeri AB, 1965), 52.
to comprehend and the demand on quality here will set the speed. The nature of the text is as important a factor as the ability of the reader to comprehend it.”

In a series of experiments in 1923 research Pyke used a tachistoscopic instrument that presented the text for 4 seconds with 11 second intervals. He then used the errors as a measure of comprehension and perception of oral reading on the legibility of various typographic designs. The text consisted of sense matter vowelled and vowelless nonsense. Setting a clock and arranging the apparatus four exposures were given at each session. The subject read aloud as much as he could observe and the experimenter noted all errors as well as the point reached in the text. The speed of reading method was used by Carmichael and Dearborn in 1947 to measure the visual fatigue in reading, and their research pointed out that ‘attempts by able researchers to devise a satisfactory measure of visual fatigue has been rather fruitless.” Reading is an aid to learning adding more information to the brain and one reason for this is the adaptability of the human visual mechanism and the plasticity of the human brain to form ‘a “rearranged” brain for learning to read”

As stated in Chapter 1 reading and writing ‘require schooling and practice, the deliberate shaping of the brain”

There are several facts about reading the first of which is ‘it took our species roughly 2,000 years to make the cognitive breakthroughs necessary to learn to read with an alphabet, today our children have to reach those same insights about print in roughly 2,000 days’

Our minds have been trained how to translate the symbolic characters which we perceive in spoken language. This also involves the movement of the eye while reading the ‘saccadic’. You read best what you read most, and the format and layout of text that people read on a regular basis schools the brain into reading this form of text. The brain and eye ‘habitually read rather small newsprint in short line widths and shift to the reading of books or magazines in larger type and longer lines without noticeable discomfort.”

The reading public is used to reading in these formats adding different styles of reading in different situations accordance to our knowledge and brain activity, and this is a result of the plasticity of the brain and the reader being familiar with the text presented in newspaper, book or magazine format. Because of the reshaping and adapting of the brain by reading most researchers have turned to the measure of output in a

---

75 Bror Zachrisson, Studies in Legibility of Printed Text (Uppsala Sweden: Almqvist & Wiksell's Boktryckeri AB, 1965), 23.
76 Ibid., p47.
performance test.\textsuperscript{83} In the light of what has been said speed of reading is not an conclusive method for checking readability. If the same piece of text is read over and over the piece of text becomes more readable as the brain adapts and learns so it would be almost impossible to get an objective result. By reading the same piece of text the results are less than objective in their conclusion regarding the data considered by them. But if the subject reads different pieces of text how can they be compared unless it contains all the same words. To overcome this problem a specific test with preliminary drills have been designed (see figure 29).

**Chapman Cook Speed of Reading Test**

Chapman-Cook in 1923 designed the *Chapman-Cook Speed of Reading Test* and the preliminary drill for this text is shown in figure 29. ‘This test has been proven to produce a pure test of speed of reading performance uncomplicated by a comprehension factor.’\textsuperscript{84} Using the *Chapman-Cook Speed of Reading Test* for adults (this included college students and high school seniors) ‘the average percentage in accuracy is 99.7. Therefore, the researcher virtually has a pure test of speed-of-reading performance uncomplicated by a comprehension factor.’\textsuperscript{85} The difference in typefaces used in the items was a single variable. The test contained 30 items of 30 words in each. The vocabulary used was relatively simple. Each item contained one word to spoil the meaning. This word had to be crossed out by the reader. The following is an example of an ‘item’ with ‘nail’ as the misplaced word:

```
There was a fire last night, and five houses were burned to the ground.
It all happened because someone was careless and threw a nail into the
waste-paper basket.\textsuperscript{86}
```

\textsuperscript{84} Ibid., p21.
\textsuperscript{85} Ibid., p21.

Tinker Speed of Reading Test

Building on the success with the accuracy of the Chapman-Cook reading test (99.7%) an extended version of Chapman-Cook test was produced in the Tinker Speed of Reading Test which consisted of 450 items of 30 words each in two forms i.e., Form I and Form II, and is designed to measure the ‘output’ of reading through comprehension. The Chapman-Cook test took only 1 minute 45 seconds; the extended Tinker speed of reading test took place over 30 minutes on each form. The comprehension accuracy as with the Chapman-Cook test was nearly 100%. Speed of
reading performance in continuous text has been adopted by researchers such as Carmichael and Dearborn in 1947, G.W. Ovink in 1938, Griffing and Franz in 1896 and Baird in 1917. The pitfalls to be avoided in Tinker’s speed of reading test that is the reading performance method by speed of reading or accuracy in identifying characters or words as employed to measure legibility were outlined by Tinker in his publication *Legibility of Type* as follows:

(a) The reading material must be uncomplicated by comprehension difficulties.
(b) Sets of reading materials employed in comparisons must be of equal difficulty.
(c) Enough reading material and a sufficient number of readers must be used to establish beyond question the accuracy of the findings. A brief paragraph or two and 10 to 15 subjects will not do.
(d) There must be an adequate check on comprehension. Except in the study by Tinker and Paterson, few investigators have checked comprehension. “Reading” without understanding is not reading.
(e) Actual printing practice must be duplicated. Photographical enlargements or reductions as used by some investigators are not satisfactory in studying variations in size of type, line length, etc.
(f) Approved statistical methods of analyzing results are essential. Differences obtained in comparisons are unimportant unless they are statistically significant.
(g) To be adequate, any experimental design for studying legibility of print must incorporate the above points.87

The time-limit method and the work-limit method used in the speed test method produced perfectly correlated results by using both the original *Chapman-Cook Test* and the longer *Tinker Speed of Reading Test*. Tinker concluded that ‘it would seem, after reviewing all the literature in the field, that speed-of-reading performance is one of the most satisfactory methods for investigating legibility of print’.88 Legibility is based on the ease with which one letter can be distinguished from another. Readability is the ease with which the eye can absorb the message and move along the line. So speed of reading and understanding the text, that is, being able to identify a misplaced word would be a good indication of legibility and readability on formatted text which would be text based in a format of a real life situation of reading. There are two types of error when reading: ‘one, oral reading error, and two, silent reading (perception or comprehension) error’.89 According to Bror Zachrisson ‘speed seems to be considered the most natural quality to measure in legibility test. Comprehension errors are less often used as the main criterion.’

88 Ibid., p23.
Eye movement while reading

Dodge and Benedict (1951) studied the psychological effect of alcohol on eye movement and observed that ‘eye movement exists for the sake of unconfused vision… For our purpose it is a further advantage that they are thoroughly habituated.’

There are three kinds of eye movement: one, the ciliary muscle causes contraction and expansion of the lens, two, the eye is the opening and closing of the papillary aperture, and three, the eye-ball movement activated by the six external eye-muscles. The movement of the eye-ball is what is measured in ‘eye-movement’ for reading. Corneal reflection or electrical methods have also been employed in the measurement of eye movement. When reading, the eye moves in quickly moves from one fixation to another along a line of print called saccadic moves (see figure 30). ‘We identify only ten or twelve letters per saccade: three or four to the left of fixation, and seven or eight to the right.’

The fixation pauses consist of periods of clear vision and that occur when reading, and the saccadic interfixation moves are so rapid no clear vision is possible. ‘On the average, pauses take 92 to 94 per cent of the reading time, and movement takes 6 to 8 per cent’ This conclusion came from a study by Tinker to determine the relation of eye movement time to pause-duration time in reading and was published in the Journal of Educational Psychology, 38 (January 1947), pp. 1-10, ‘Time Relation for Eye-Movement Measured in Reading.’ With the advance in technology the electrical recording of eye movement became the method of choice because it is more flexible than the corneal reflection method. ‘We know of no other voluntary action which is so completely withdrawn from voluntary control as the eye movement.’

Tinker in his 1936 study of ‘Readability and Validity of Eye-Movement measures in Reading’ published in the Journal of Educational Psychology, 19 (December 1936), pp. 732-46 found that the measurement of eye movement method was a satisfactory and reliable method for studying legibility of print. And from these findings Tinker came to the conclusion that eye-movement measures provide valuable supplementary information in investigating legibility as the study covered reading materials varying in length and difficulty. Eye-movement also measured speed of reading performance, and this helped to give more a complete indication in legibility of print thus the combining of several factors give a more rounded result.

---

The length of time or the length of work period is another method used to study legibility. In 1936 Tinker and Paterson carried out the first investigation into the ‘adequacy of short time limits in measuring legibility’, and for the purpose of this study assumed that any measurable effect obtained during a brief reading period of 1 minute and 45 seconds would also be present in longer periods of reading. The following were the results of the effect in speed of reading of the typefaces by comparing Cloister Black (Old English) with Scotch Roman:

- For 80 readers, 1 3/4 minutes: 11.6 per cent
- For 91 readers, 5 3/4 minutes: 12.4 per cent
- For 94 readers, 10 minutes: 14.1 per cent.

They concluded from this “that the initial retarding effect persists, and even increases a little, as the reading periods are lengthened.”

Tinker concluded from this and other research studies that ‘one may safely conclude from these studies that reading for relatively short periods yields a valid measure of legibility. Such work as Pyke (1926) and Weston (1917, 1935) advocate and use work periods as short as 1 minute.’

Legibility of print was a major concern for editors, printers, ophthalmologists and educators for more than a century. Prior to the nineteenth century ‘the main concern was with the esthetic appearance of print. With improved technology of printing, two additional factors entered the picture: Economy of printing and traditional practices.’

Tinker stated in his publication *Legibility of Print* that ‘prior to the 1900 there were very few experimental studies reported, but after 1925, research in the field has expanded’.

---


---

96 Ibid., p27.
97 Ibid., p3.
markedly’. In 1926 Pyke’s survey pointed out that only a few investigations made before 1926 define legibility and he illustrated this by referring to the following authors:

**Author and year.**

- Javal, E (1878-81 & 1905).
  - **Judgement**: Of both a type-face and individual letter: ability to read far off; ability to be read in a dim light.

  - **Judgement**: Of a type-face: ability to be read quickly and easily.

- Cohn, H. (1883).
  - **Judgement**: Of letters: ability to be read easily, ‘that is, fluently, for a good length of time and comfortably at a distance of 20 in. or 1/2 m’.

- Pergens, E. (1904).
  - **Judgement**: Of individual letters: ability to be read far off.

  - **Judgement**: (i) He distinguishes legibility from visibility. The latter refers to the ‘mark made upon the paper by a letter, and is measures by the distance from the eye at which the letter whole, if alone, ceases to be distinguishable from the paper, or, if among other letters, becomes merged with them.
  - (ii) ‘Legibility, on the contrary, consists in it being possible to define clearly with the eye the design of the letter, that is, its contours, and therefore the ensemble of the letter of a single word. A given character is legible only at a certain distance, which is shown by (the reader’s) visual acuity. Legibility… stands in direct relation to (1) letter-shape, (2) ratio of letter-height to letter-width, (3) thickness of main-stroke and hair line, and (4) the internal and surrounding white spaces.’

  - **Judgement**: Of individual letters: ability to be recognized peripherally.

- Bentley, M. (1921).
  - **Judgement**: Of a type-face: ability to be read quickly and easily.

One of Pyke’s major conclusions has never been disputed, viz. ‘Large typographical differences must be present before it is possible to say that there is any difference in the objective legibility of types.’

The following factors relating to reading were outlined by Bror Zachrisson in his 1965 publication *Studies in the legibility of Printed Text*.

2. **Text.** Purpose: Recreation or work-type length.
3. **Typography and technical factors.** Appropriateness of technical means used.
4. **Situation.** Oral or silent reading. External conditions (lighting, position, environment etc.).

---

100 ibid., p60.
In relation to the first point above Zachrisson explains: ‘Increasing importance should be attached to the readers. Difference in age, sex, education, nationality, handicaps, etc., causes a good deal of variation in the results of research. Similarly, the reading material must not only be studied in relation to the reading act, but should be considered as to its function.’

These matters should be taken into account when considering research into readability and legibility of printed typography. In the earlier years the opinions and recommendations expressed on the subject of legibility formed the basis of casual observation.

Methods and instruments that were used to study different aspects of reading

The methods and instruments that were used to study different aspects of reading were as follows. The tachistoscope was one such instrument and came in three main types: the photo-shutter, the fall and the mechanical. The first two use a light source and project a slide image with a different timing gear. However, the fall timing gear had the disadvantage of causing noise during operation and this caused problems in an experimental situation a distraction for the reader. The photographical shutter did not have the noise disadvantage and was easy to arrange for manipulation by the subject. The mechanical instrument showed the actual image though not a projection of it. The advantage of this type of tachistoscope was that it was closer to the natural visual or reading situation than some of other types of instrument used at ordinary reading distance. In Pyke’s research (1926) the apparatus used by him showed the text for four seconds but was a timing device only and not a proper tachistoscope.

The tachistoscope advantages were:

Quantitative observations along with recording errors of perception, indirect vision, span of attention, influence of size, form, light blur, other external factors of visibility, and interesting details, such as cues to recognition.

The disadvantages of the tachistoscope are that ‘the results may not be generalized; to be valid, data on reading requires a more natural reading situation. A pre-fixation point is used for orientation.’

The reading speed test such as the Chapman-Cook test and Tinker Speed of Reading test were conducted under normal reading materials producing results corresponding to normal reading.

The ophthalmologist used an instrument called the perimeter to study the nature of the field of vision. The principle of this instrument is that the eye is fixated at a point

---

104 Ibid., p66.
105 Ibid., p66.
of indirect vision that included colour-fields and monochrome fields, and both were established by introducing stimuli. Indirect vision aids orientation as well as the creation of pre-Gestalts (pre-percepts and perception). Indirect vision also helps to create the atmosphere of reading and this includes the localisation in a situation, the feel of the book, the environment and the context with typography the layout and design of the type. The fixation point in reading also aids concentration. Experiments with indirect vision have been combined with tachistoscope results.106

The ‘vista’ (1962) was an instrument invented by the Advertising Research Foundation (ARF), and with this instrument it was possible to study the influence of speed of presentation, focal variation, distance and binocular rivalry.107

Readers’ opinions were assessed by means of interview or questionnaires. Pyke used this method and got results that agreed more or less with the results from speed tests on legibility.108 In Pyke’s questionnaire:

Sixty individuals were canvassed for their opinions as to the relative merits of the eight types. They were expressly asked to ignore the aesthetic aspect. They were given one sheet of sense material in each type. They gave that information they could about their visual acuity.109

Tinker and Paterson used readers’ opinions on several occasions and in 1931 found positive correlations with the speed of reading.

Bror Zachrisson study in the Graphic Institute in Stockholm over a ten-year period investigated the problem of typefaces, type size and other elements of typography. Subjective and objective criteria of legibility were used. The subjective experiments were summarised in the following table:

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Variable</th>
<th>Criterion</th>
<th>Measure</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>10. (C)</td>
<td>Typeface</td>
<td>Legibility</td>
<td>Opinion</td>
<td>No significance</td>
</tr>
<tr>
<td>13. (C)</td>
<td>Type size</td>
<td>Legibility</td>
<td>Ranking</td>
<td>Significant</td>
</tr>
<tr>
<td>3. (A)</td>
<td>Typography</td>
<td>Evaluation</td>
<td>Ranking</td>
<td>Significant</td>
</tr>
<tr>
<td>16. (A)</td>
<td>Typography</td>
<td>Congeniality</td>
<td>Ranking</td>
<td>Significant</td>
</tr>
<tr>
<td>17. (A)</td>
<td>Typography</td>
<td>Congeniality</td>
<td>Matching</td>
<td>Low</td>
</tr>
</tbody>
</table>

107 Ibid., p68.
108 Ibid., p69.
110 Bror Zachrisson, Studies in Legibility of Printed Text (Uppsala Sweden: Almgvist & Wiksell’s Boktryckeri AB, 1965), 166.
Experiments regarding familiarity, reading and discerning performance.

Children = C. Adults = A.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Variable</th>
<th>Criterion</th>
<th>Measure</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. (A)</td>
<td>Typeface</td>
<td>Familiarity</td>
<td>Recognition</td>
<td>Low significance</td>
</tr>
<tr>
<td>2. (A)</td>
<td>Letters</td>
<td>Familiarity</td>
<td>Recognition + reproduction</td>
<td>Low significance</td>
</tr>
<tr>
<td>4. (C)</td>
<td>Typeface</td>
<td>Legibility</td>
<td>Oral reading</td>
<td>No significance</td>
</tr>
<tr>
<td>5. (C)</td>
<td>Typeface</td>
<td>Legibility</td>
<td>Silent reading</td>
<td>No significance</td>
</tr>
<tr>
<td>6. (C)</td>
<td>Typeface</td>
<td>Discernibility</td>
<td>Tachistoscope</td>
<td>No significance</td>
</tr>
<tr>
<td>7. (C)</td>
<td>Typeface</td>
<td>Discernibility</td>
<td>Focal varistor</td>
<td>No significance</td>
</tr>
<tr>
<td>8. (C)</td>
<td>Typeface</td>
<td>Discernibility</td>
<td>Perimeter</td>
<td>No significance</td>
</tr>
<tr>
<td>9. (A)</td>
<td>Typeface</td>
<td>Discernibility</td>
<td>Binocular rivalry</td>
<td>Significant</td>
</tr>
<tr>
<td>11. (A)</td>
<td>Typeface</td>
<td>Legibility</td>
<td>Oral reading</td>
<td>No significance</td>
</tr>
<tr>
<td>12. (A)</td>
<td>Typography</td>
<td>Legibility</td>
<td>Silent reading</td>
<td>No significance</td>
</tr>
<tr>
<td>12. (A)</td>
<td>Typography</td>
<td>Legibility</td>
<td>Silent reading</td>
<td>Low significance</td>
</tr>
<tr>
<td>15. (A)</td>
<td>Typography</td>
<td>Legibility</td>
<td>Eye-movement</td>
<td>No significance</td>
</tr>
</tbody>
</table>

Reading habits were taken into account by the above experiment, and the type sizes judged as most legible were those that were most commonly used by the above respective age groups. The objective criteria included experiments with typefaces and typography and were applied in normal reading situations that included oral and silent reading. The results were similar to those found by Pyke’s experiments in 1926 and by Ovink in 1938 who found that ‘the common type are equally readable’. Also Zachrisson’s experiments demonstrated significant differences between reading skill groups except in the experiment with the tachistoscope where there was no significant difference between different reading skills groups. Part of Zachrisson results show ‘that it is advisable to relate legibility to a particular group of readers, defined by age and experience’ for the following reasons:

11-year-old children read small type as fast and as well as larger sizes. Children as well as adults judge type and typography on the basis of wholeness rather than details.

Our investigations suggest that it would be worthwhile to continue studies of the legibility of printed text and its congeniality value on different levels of reading maturity and of education, as well as with different content material.

It may be said that even with the extent of the research done by Zachrisson his research does not cover everything and does not give a complete picture. The fact that Zachrisson in his conclusion admits that more research into legibility and readability is necessary due to the amount of contributing factors that can affect both legibility and readability.

---

The following is an outline of some of the research into readability and legibility for both printed typography and screen typography as ‘an endeavour to bring to a focus in the present the theories and research of the past’. ¹¹⁴ This research falls into different fields, for instance, studies into general problems and studies into particular problems of which include type design, type size and typography and the congeniality of typography. Research has been undertaken on the legibility of printed text under the following headings: (a) Contrast in thickness and thinness in the characters; (b) Criterion of legibility; (c) Definition of legibility; (d) Faces of type; (e) Illumination; (f) Indentation; (g) Leading; (h) Legibility of letters; (i) Length of lines; (j) Margins: (k) Paper and ink; (l) Projectors (characters which project above or below, or both in the lines of text); (m) Punctuation: (n) Serifs; (o) Size of type; (p) Spacing; and also (q) ‘The Ideal type’.

**Screen typography verses Printed typography**

**Birth of computers**

As early as 1833 the concept of the computer was introduced by Charles Babbage when he began to consider the construction ‘of something he called an Analytical Engine’¹¹⁵. This so-called analytical engine came after an improved working model of his 1821 machine of log calculations which ‘was an improvement but not enough to match the overall complexity of the system’¹¹⁶. His machine was before its time but the technology to achieve his vision was not available. In later times inventors such as Blaise Pascal, Otto Steiger, Konrad Zuse and Howard Aiken developed a form of computer. The computer has to have a memory, a decision-making unit, and a functional flexibility to be programmed.¹¹⁷ The programmable feature of the computer is what changed the initial computers from a machine that counts to a machine that communicates in the form of text and reading among other operations. High resolution printing of books and magazines are printed so the individual dots (i.e. the smallest basic element of a halftone) seem invisible while in newspapers the dots are more visible ‘— it’s about the total user experience. For print, this experience pretty much equates to type and photo quality.’¹¹⁸ New guidelines are required to make typography readable on screen, and these guidelines are determined by human characteristics, and as already stated ‘— it’s

about the total user experience’, and this is a different reading experience to reading from print. As was pointed out by McLuhan in *The Gutenberg Galaxy* ‘in beholding this new thing man is compelled to become it’. By ‘becoming it’ the human brain adapts and alters to computer but the user’s experience is important and the design of the experience will contribute and aid in the usage. The user of the new technology partakes and delves into the new format and layout working and changing to the new technology.

**The computer memory and the human memory**

The computer and the human brain have similar traits like memory, i.e. electrical pulses along neurons stimulation in the nerve cells to create reactions; in a computer electrical pulses power it to perform the function it is programmed to operate. ‘A memory can retain a certain maximum amount of information recall the information and use it for the function the computer was programmed for. This information can always be converted into an aggregation of binary digits, i.e. “bits”,’¹²⁰ for example, a memory that can hold a thousand eight-place decimal number ‘would have to be assigned a capacity of 1,000 x 8 x 3.32 bits’. Using John Von Neumann (a renowned mathematician) calculations to the memory used to remember and recall the alphabet the following would apply ‘one such letter being a 2 x 26 + 35 = 88… evaluated at \( \log_2 88 \approx 6.45 \)’ (2 for upper and lower case letters, 26 being the numbers of letters in the alphabet, and 35 the usual numbers of punctuation marks, numbers etc.), so the memory of a human that can hold for the alphabet alone ‘a thousand such letters has a capacity of 6,450 = 6.45 x 10³ bits.’¹²¹ The computer memory and the human memory can be seen to have similar traits that of holding, retaining and using information. The complexity of the memory of the computer runs in parallel with the complexity of the human brain and the ‘bits’ i.e. the binary digits, are the electronic forms of the Roman alphabet.

**Research into the difference of reading from paper and reading from screen**

With the invention of computers and the widespread reading of electronic text research into the difference between reading from paper and reading from screen commenced in earnest. Analyses into reading concentrated on outcome and process measures. ‘Outcome’ related to the amount of information received, accuracy of recall and time taken to read the text. As with printed text the outcome is measured by speed, accuracy,  

---

fatigue, comprehension and preference. ‘Process measures’ demonstrated the way the text was read and the way the reader manipulated the text.\textsuperscript{122}

Type has suddenly become widely accessible and affordable; it is output in hundreds of thousands of desktop laser printers beyond the control of the professional publishing channels that have tightly regulated its nature and form for half a millennium.\textsuperscript{123}

The use of computers led to increased efficiency and improved performance in text by ‘professional publishing channels’ as well as giving non-professional publishing channels access to type and printing.

As soon as you inject a book with links and connect it to the Web--as soon as you “extend” and “enhance” it and make it “dynamic”--you change what it is and you change, as well the experience of reading it.\textsuperscript{124}

The difference in perception between printed and electronic text has also presented a different perception of legibility with typography on screen. Printed material presents a slower more comfortable outcome (sitting silently in a library studying quietly or sitting in a comfortable chair reading a book). Outcome and processes is where the difference is found. In research of outcome, the fields of speed, comprehension, accuracy and fatigue, were investigated.

**Research of silent reading from screen versus paper**

The research of silent reading from screen versus paper, experimental findings by Anita V. Kak in 1981 and others such as Wright and Lickorish in 1983; Gould and Grischkowsky in 1984; Smedshammer et al in 1989 and Muter et al in 1982, all found that silent reading is significantly slower on screen than reading from paper. By using different methods and means of calculations the performance deficit when reading from screen was found to be something between 20% and 30%.\textsuperscript{125}

Anita V. Kak in 1981 as a member of Department of Reading Northeastern Illinois University Chicago carried out research on continuous text on screen and paper. Up till 1981 most research dealt with the display quality of characters. Kak’s research method was as follows:

Three basic tasks were utilized: (1) scanning for target letters in a random-letter noise field; (2) Reading a standardized reading test (Nelson-Denny Reading Test) presented on a CTR and answering comprehension-testing questions with paper and pencil: (3) taking the traditional paper-format version of the Nelson-Denny


\textsuperscript{123} Bigelow et al., eds., *Fine Print on Type, The Best of Fine Print Magazine on Type and Typography* (San Francisco: Fine Print & Bedford Arts, 1989), Sandra Kirshenbaum: ‘Bitwitched, Bothered, and Bewildered: Type 1987’, 131.

\textsuperscript{124} Nicholas Carr, *The Shallows* (London: Atlantic Books, 2010), 103.

test. In Experiment I, each subject performed all three tasks. In Experiment II, twelve additional subjects performed only task 2 and 3.

As a result of her experiments two basic conclusions emerged. First, that ‘legibility criteria may be excessively strict when applied to tasks involving reading of connected prose text was supported’, and secondly, that reading scores from CTR when conditions are optimised can equal the scores obtained from reading from paper. George R. Klare functions of readability: ‘To indicate ease of understanding or comprehension due to the style of writing’ are still in use and can adapt to electronic format as well as on paper comprehension was still a factor for detecting legibility in the early 1980s.

In 1984 Richard S. Kruk and Paul Muter, Department of Psychology, University of Toronto, Ontario, Canada carried out research into speed of reading with text on video screen versus printed text, and this involved ‘three experiments into the findings of slower reading of text from a video screen than from a book was replicated, and several possible reasons for this effect were explored’. He concluded that format (characters per line and lines per page) and interline spacing (leading) affect the speed of reading.

In 1990 Cliff A. Knight, Andrew Dillon, and John Richardson compared reading the same text in four formats, two in Linear — Word Processor and paper and two in hypertext—TIES and HyperCard. Measurements were made of time and accuracy as the subjects were required to answer twelve questions on the text and their movement through the document was recorded. The results showed no significant difference between paper and word processor file save that readers in both hypertexts were significantly less accurate than reading from the paper documents.

In the 1980s’ fatigue was again a method of preference when investigating reading from microfiche, paper and VDU using Visual Fatigue Graphic Rate (VFGRS) and the Feeling-Tone Checklist (FTC, Pearson and Byars, 1956), and the earlier investigations were found to been affected by the quality of the screens. In research 1989 ‘Visual Performance on CRT Screens and Hard-Copy Displays’ Jefferey L. Harpster et al found that there were three experiments for assessing the effect of hard-copy print and CRT screens of different resolution/addressability ratios (RAR), and provided three different display models to demonstrate this by using an IBM personal

---

computer and a Princeton Graphic Terminal: one, capital letters in high-RAR mode, two, capital letters in low-RAR mode, and three, capital letters in high-RAR mode programmed to simulate the low-RAR mode. Same size letters were also presented on hard-copy print. The research concluded that ‘accommodative accuracy with hard-copy print and high-RAR CTR screens were significantly better that low-RAR. Secondly, visual search performance was significantly better for hard-copy display and high-RAR CTR displays than for low-RAR CTR displays.’ The conclusion for reading from different quality screens do not ‘find reading from VDUs intrinsically fatiguing but that performance levels may be more difficult to sustain over time when reading from average quality screens.’ As screen quality increases over time this problem of fatigue may be minimised. It appears that with the advances in technology such as Apple’s Retina Display which refers to a screen whose pixels are so closely packed that, when held at what Apple considers to be the ‘normal’ distance from the user’s face, you would not be able to make out individual pixels may have an altered these facts.

Comprehension studies in relation to reading on screen verses paper

Comprehension as identified by George R. Klare is again an aspect that has been studied in relation to screen verses paper. The issue of comprehension has not been as fully researched, as Dillon in his paper observed: ‘Reading from paper versus screen: a critical review of the empirical literature’ points out this could be ‘in no small way due to the difficulty of devising a suitable means of quantification i.e., how does one measure a reader’s comprehension?’ Dillon goes on to say: ‘Post-task questions about the content of the reading material are perhaps the simplest method of assessment, although care must be taken to ensure that the questions do not simply demand recall skills.’

Kak (1981) used the Nelson-Denny test on paper and VDU and found that comprehension questions were answered by using hand with pen on paper, and observed that there was no significant effect for the presentation medium. Cashman in 1986 comparing paper, microfiche and VDUs found a similar result. Cashman also noted that a negative correlation existed between reading speed and comprehension and that ‘comprehension tended to be higher for slower readers’. Other research into differences between reading from paper and screen found that the familiarity with the

---

medium aided the speed and comprehension of the text material. Susan Belmore in 1985 suggested in her paper ‘Reading computer-presented text’ that ‘the performance decrement was due to the subjects’ lack of familiarity with computers and reading from screens – a factor commonly found in this type of study.’\textsuperscript{134} It is suggested that this latter observation is less relevant in modern times due to the increased familiarity of readers reading books from screen. ‘Past research has demonstrated that reading efficiency is lower from standard computer displays of the 1980s than from paper.’\textsuperscript{135} In Muter and Maurutto 1991 research the subjects were asked to answer questions about a short story read either on paper or screen immediately after finishing the reading task. The conclusion was as follow: ‘These experiments demonstrate that reading from computer screens that are readily available in 1991 can be equivalent in speed and comprehension to reading from a book.’\textsuperscript{136} The amount of PC is on the increase and the more people that have and use PC the more people will become familiar and a habit of reading on screen will develop, thus rendering the early research out of date.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dell (#M)</td>
<td>5.4</td>
<td>42.1</td>
<td>133</td>
<td>246</td>
</tr>
<tr>
<td>HP &amp; Compaq (#M)</td>
<td>21.3</td>
<td>95.0</td>
<td>130</td>
<td>205</td>
</tr>
<tr>
<td>IBM &amp; Lenovo (#M)</td>
<td>18.0</td>
<td>43.5</td>
<td>64.8</td>
<td>107</td>
</tr>
<tr>
<td>Acer (#M)</td>
<td>1.7</td>
<td>9.5</td>
<td>28.8</td>
<td>79</td>
</tr>
<tr>
<td>NEC &amp; PB (#M)</td>
<td>9.3</td>
<td>25.7</td>
<td>26.5</td>
<td>38</td>
</tr>
<tr>
<td>Apple (#M)</td>
<td>16.2</td>
<td>17.6</td>
<td>17.2</td>
<td>33</td>
</tr>
<tr>
<td>Toshiba (#M)</td>
<td>4.6</td>
<td>15.9</td>
<td>24.2</td>
<td>41</td>
</tr>
<tr>
<td>Gateway (#M)</td>
<td>3.8</td>
<td>18.0</td>
<td>16.5</td>
<td>32</td>
</tr>
<tr>
<td>Total PC Sales (#M)</td>
<td>201</td>
<td>492</td>
<td>810</td>
<td>1,300</td>
</tr>
</tbody>
</table>


\textsuperscript{135} Paul Muter and Paula Maurutto, ‘Reading and skimming from computer screens and books: The paperless office revisited?’ \textit{Behaviour & Information Technology}, 1991, 10, 257-266.
\textsuperscript{136} \textit{Ibid.}, p257-266.
Serif versus sans serif which is more legible

Another aspect in legibility is the serif versus sans serif typefaces. Pyke’s 1926 study found that sans serif in the study ranked second in order of legibility, being 18% less legible than a Standard Old Style face but it was also 30% ahead of the third ranked a standard Modern style. Tinker and Paterson (1932) in their research ‘Studies of Typographical Factors Influencing Speed of reading: X. Styles of Typefaces,’ *Journal of Applied Psychology*, 16 (December, 1932), pp. 606-13, studied ten typefaces, and Kabel Light being the only sans serif, the other nine typefaces were serif which included Old Style and Didone faces and it was found that the difference of legibility between them the nine typeface was not statistically reliable showing very little of a difference in speed of reading stating that ‘the serifless type, Kable Light, is read as rapidly as ordinary type, but the readers do not prefer it.’ In the readers’ opinions of relative legibility Kabel light came in ninth place. The difference in speed of reading had Scotch Roman standard at the top of the ranking 0.0 and the difference in per cent in order of readability Garamond +0.4%, Antique -2.0, Bodoni -1.0, Old Style -1.1, Caslon Old Style -1.3, Kabel Light -2.2, Cheltenham -2.4, American Typewriter -4.7, and in tenth place Cloister Black -13.6. Sans serif typefaces became ‘the typographical symbol of the Modernist spirit, broadly applied in all kinds of reading material.’ The use of sans serif typefaces was found not to be the preference of the reader but by designers. The debate on serif verses sans serif did not start with the invention of computers and digital typography, Jan Tschichold in his book *The New Typography* of 1928 stated ‘it must be laid down that sanserif is absolutely and always better’ This led to the sans serif typefaces eventually becoming the typographical symbol of the Modernist spirit. The application of sans serif to all kinds of reading material ‘happened not in response to readers’ preferences but because of designers’ conceptual beliefs; readers were exposed to the sans serif to such a degree that they eventually got used to it. In Tinker’s ‘study of Typographical Factors Influencing Speed of Reading, X. style of typeface’ in 1932 the readers were asked to rank the same typefaces in the study based on their preferences, and Kabel Light the only sans serif face in the study was judged as the second most illegible of all the ten typefaces studied. However readers who were exposed to sans serif for long periods of time eventually got quite used to it: ‘We read

---

best what we read most’. In 2001 when studying **Verdana** (sans serif) along with Times and Georgia (both serif typefaces) in relation to reading speed in conjunction with accuracy and the participants’ perception of typeface legibility, Michael Bernard, Bonnie Lida, Shannon Riley, Telia Hackler, & Karen Janzen ‘Comparison of Popular Online Fonts: Which Size and Type is Best?’ in 2002, concluded that:

Verdana was the most preferred font, while Times was the least preferred. Thus it seems that the Georgia and Times serif fonts are considered more attractive, but they are generally less preferred. Of the fonts studied, Verdana appears to be the best overall font choice. Besides being the most preferred, it was read fairly quickly and was perceived as being legible.\(^{142}\)

S. Morrison and J. Noyes in ‘A Comparison of Two Computer Fonts: Serif versus Ornate Sans Serif’ produced results showing that reading times for the serif typeface (Times New Roman) was faster than reading the ornate sans serif typeface (Gigi). Comprehension was found to be better for the serif typeface than the ornate sans serif typeface.\(^{143}\) These results are supported by the findings of M. Bernard, M. Mills, M. Peterson and K. Storrer in ‘A comparison of Popular Online fonts: Which is Best and When?’ (2001). They found that the typefaces that were perceived as being most legible were **Courier, Comic, Verdana, Georgia** and **Times**.\(^{144}\) The method used involved participants reading twelve passages, each of which comprised of a typeface from one of the twelve typefaces. The passages were written at approximately the same reading level and discussed similar material. The passages were an average of 1032 words per passage. The horizontal margins were set at 640 pixels. The typeface was set in black on a white background. The participants were positioned at the fixed distance of approximately 57 cm from the computer screen. The passages contained 15 randomly placed substitution words. The participants were asked to read ‘as quickly and as accurately as possible’ and to identity the substituted word. Accuracy and its associated effect on reading time determined the typeface legibility.

Ole Lund found that nearly all of the 28 reviewed studies (conducted between 1896 and 1997) showed ‘(of a surprising total of 72 identified studies) lack internal validity’\(^{145}\) and ‘this lack of internal validity was largely due to confounding factors that resided in the stimulus material caused by the researchers’ inadequate domain


knowledge (about typography). A 2002 study by R. A. Morris, K. Aquilante, D. Yager and C. Bigelow (Bigelow is a type designer) ‘Serifs Slow RSVP Reading at Very Small Sizes, but Don’t Matter at Larger Sizes’ published in the *SID Symposium Digest of Technical Papers*, vol. 17(2), pp. 244-247, showed that scientists used test material designed to minimise the disruptive influences of other variables. The test materials were in Bigelow’s typeface Lucida where one typeface had serifs and the other had not. The method had the subject read rapidly the words exposed on a screen placed at a distance. The results showed that the subjects found it more difficult to read the slab serif typeface in small sizes than the sans serif typeface, and that there was no difference in the results for larger sizes. When the serif typeface was used it was more tightly spaced than normal to unify the spacing, and the sans serif typeface was more loosely fitted so the typefaces had the spacing distorther which distorted the true representation of the typefaces and this the spacing of the words. ‘Whatever the reason, the study tells us that serifs are not by default a legibility-improving feature.’\textsuperscript{147} Spacing is another factor that affects legibility. It may also be said that since the typefaces were not presented to the subject in the format that they were designed for sans serif loose spacing and the slab serif typeface more tightly spaced that the default spacing or as the designer designed the spacing to aid in its presentation that the results did not give a true result as the spacing were distorted and so are the results.

Johnson described the essential or structural and forms of character in the design field as ‘the simplest forms which preserve the characteristic structure, distinctiveness, and proportions of each individual letter.’\textsuperscript{148} The classic goal of type design ‘is to achieve harmony and balance between individual forms. Within words, a letter should never stand out; it should cohere with neighboring letters, in order to better form a word unit and sublexical unit as well.’\textsuperscript{149} Letter perception is an important stage of the reading process. With existing research ‘it is now clear that letter perception provides a critical front end for reading because letters are functional units; they are independent pieces of the word.’\textsuperscript{150}


\textsuperscript{150} Ibid, T. Sanocki, M. C. Dyson, ‘Letter processing and font information during reading: Beyond distinctiveness, where vision meets design’.
Legibility of letters by comparing characters in the same typeface

The research into the investigation of legibility was the study of the relative legibility of letters by comparing the different characters within the alphabet as legibility is based on the ease with which one letter can be identified from the other. With the advances in technology the reading public has now more access to typography and digital typography it use and to format the type. The information gathered since the first printing with movable characters forms the bases of digital typographical knowledge and the present shapes of characters. Tinker, *Legibility of Print*, Ames, Iowa U.S.A.: Iowa State University Press, 1963 found that certain distinguishing letter features aid legibility more than others, and that lowercase letters such as ‘b’, ‘d’, ‘p’, ‘q’ and ‘k’ are among the most easily distinguishable due to the descending and ascending elements and well-defined x-height features. The following is a range of researchers, test methods, typefaces using lowercase and well among the most easily distinguishable legibility more than others.

Iowa State University Press, 1963 found that certain distinguishing letter features aid legibility more than others, and that lowercase letters such as ‘b’, ‘d’, ‘p’, ‘q’ and ‘k’ are among the most easily distinguishable due to the descending and ascending elements and well-defined x-height features. The following is a range of researchers, test methods, typefaces using lowercase and well among the most easily distinguishable legibility more than others.
Q → G. The research into legibility of single letter and groups of letter found that characters of certain shapes which fit into several different groups can be misread for each other an example of this is shape with a mix of straight and curved lines (e, c, a, s, n, u, o) another example of character misreading is the group of narrow letters with a single vertical stroke (j, i, l, t, f). The same can be said of groups of round shaped characters in the uppercase (O, Q, C, G, D). Tinker (1963) in his research from seven studies on the ‘Legibility of letters and Digits’ revealed the following trends: Letters of high legibility: d m p q w. Letters of low legibility: c e i n l. Letters of medium legibility: j r v x y. The misreading of characters is a fact no matter if the typography is on screen or printed and it seem to be an important aspect of legibility and readability or a stumbling block in decoding the spoken sounds in symbols. Lower case characters are more distinct than their upper case equivalent and thus making the misreading less than with the uppercase.

The adoption of minuscule (lowercase letters) as a book script ‘is significant for the historian of reading insofar as it contributed, in conjunction with word separation, to giving each word a distinct image. Modern psychologists call this image the Bouma Shape’. The name comes from the Dutch psychologist Herman Bouma.

Microsoft’s Advanced Reading Technologies and research into screen typography

Microsoft’s Advanced Reading Technologies team member Kevin Larson in 2010 outlined the then ongoing research into the legibility of single characters in an interview/questionnaire with Jamie Chamberlin. In the interview he explains how subjects are exposed to single characters for a brief period of time and asked to identify them. He also explained the rate of accuracy and recorded the errors made. This information illustrates what characters are confused with each other. ‘Drawing from that data, we can determine whether we can make each letter more legible but still conform to the font’s personality.’ Other research from the Microsoft’s Advanced Reading Technologies team confirmed that reading on computer screens causes more eye fatigue than reading printed text on paper. The optometrist James Sheedy of Pacific University carried out research into the effect of muscles fatigue. One of the results of this research identified that ‘the orbicularis oculi becomes more active and your blink rate decreases’ when the text was read in too light in contrast to the background or where the text was

155 Ibid., p305.
too small (anything below 12 point). By increasing the type size and giving higher contrast in text fatigue was reduced. Another research was conducted into page layout using ‘good’ and ‘bad’ page layout. The results of this research found no difference in reading speed or comprehension. This is an example of legibility and readability overlapping each other and when identifying characters, and the understanding of them cannot be separated the human brain as it changes/develops to understand the abstract characters of the Roman alphabet.

Font tuning: a reader can tune into one specific typeface and thus read it. ‘Font tuning (FT) occurs when observers recognize a sequence of letters presented in the same font faster than in different fonts’. There has been a resurgence of interest in letter perception in relationship to reading. ‘The idea of improving legibility through research and design is not new. Modifications to increase distinctiveness have been explored by Kolers (1969), Lockhead and Crist (1980), and more recently, Beier and Larson (2010).’ This comes from the research that ‘letter perception provides a critical front end for reading because letters are functional units; they are independent pieces of the word code.’ When letters are being designed for continuous paragraphs of text, the main goal of the typeface design is to produce optimally legible letter forms. Type characters have to be distinctiveness along with the uniformity of letters. Within a word a letter should never stand out.

‘The human reader is influenced not only by the sheer clarity of the symbols and their configuration, but also by their atmosphere.’ The atmosphere can be made up of the environment the reader is in, or the atmosphere created by the layout of the typography, the different typeface can produce different atmospheres, and an example of this would be a typeface that has a shatter and broken look can portray a similar images or feelings, this would also depend on the design and layout of the text. Typographic designers incorporated commonalities ‘because they believed they were important to legibility, on the basis of their data, their data are judgments refined through training, aimed at understanding the structural relations that constitute a legible font’. This idea

159 Ibid., 2011, 133.
that commonalities are important in letter perception is supported by a group of psychological studies among which is the research of Gauthier (Isabel Gauthier, Ph.D., David K. Wilson Chair and Professor of Psychology; Professor of Radiology and Radiological Sciences Investigator), Hayward, Wong (Assistant Professor with research interests in Perceptual expertise in domains like face perception, letter perception, music reading, along with the neural basis of object recognition and the relationship between perception and emotion, conception, and consciousness) and Cheung (Ph.D. (USC)), in 2006. The results from this study ‘is that letter processing becomes more efficient because of the perceptual-processing system tunes itself to exploit regularities of a font.’¹⁶¹ What is font tuning? Font tuning consists of type parameters change type-specific input into type-invariant form and this derives from the specific properties of the type and the typeface abstract representations.¹⁶² Isabel Gauthier and Chun-Nang from Vanderbilt University, Nashville, TN. along with William G. Hayward (Ph.D. in Psychology, Professor, Associate Professor, Department Head of Psychology, research interest in object recognition, visual attention and visual cognition) and Sin-Chi Cheung from Chinese University of Hong Kong in 2006 carried out research into whether font-tuning is a strategy general to all pattern recognition or whether it is a property of expert letter recognition. Based on the assumption that print is regular in type, the typeface parameters can be used to speed up the recognition of subsequent letters.¹⁶³ The research covered Roman letters and Chinese Characters. The method used, due to the speed of letter recognition and the effect of font tuning, is hard to measure on a single letter. The following task was designed to measure the time required to recognise 100 letters in a manner similar to reading but which does not involve phonetic or lexical processing. The task is illustrated in the following screen grabs from the pdf ‘The Role of Fonts in Letter Recognition’ first the ‘Task’ and second the ‘Experiment 1: Roman letters in experts’.

2 Task  

Letter recognition is so fast, the effect of font-tuning may be hard to measure on a single letter.

We designed a task to measure the time required to recognize many (100) letters, similar to reading but which does not involve phonetic or lexical processing.

Matrix Search Task:
1- the top left letter in the matrix is your first target.
2- search the matrix from left to right (and top to bottom) until you find the target.
3- Once you found the target, the next letter becomes your new target.
4- Repeat steps 2 and 3 until you reach the end of the matrix: press the space bar (RT measure).
5- The last target you were searching for, but did not find, is your final answer (Accuracy measure).

Font could be considered ‘trivial’ for the task to recognize letter identity. However, if differences in font make letter recognition more difficult and one can assume that printed words will be font-regular, expert readers may have developed the strategy of “tuning” the font information presented as they read. Font parameters may be established and refined online while we read, and provide a source of prediction for the visual appearance of letters to some.

**Final answer:** g

---


3 Experiment 1: Roman letters in experts

- 17 Subjects
- 3 conditions (baseline, regular or mixed)
- 5 fonts were used
- All letters familiarized first
- 3, 4 or 5 targets per matrix

- no difference in accuracy between mixed and regular conditions, but experts take longer in the mixed than regular condition (and longer in both relative to baseline), independent of target number.
- Reaction times for correct responses seems to best capture the phenomenon of font tuning in this paradigm.

---

Figure 33: ‘Experiment 1: Roman letters in experts’ states the number of subjects (17), the different conditions examined (baseline, regular and mixed), the amount of typefaces used (5) and the amount of targets per matrix (3, 4 and 5). Sourced: Gauthier, I., Hayward, W.G., Wong, C-N., Cheung S-C., ‘The Role of Font in Letter Recognition’. http://www.psy.vanderbilt.edu/faculty/gauthier/publi/Psychonomics_01.pdf. Accessed 26 February, 2013.
The results: letter processing became more efficient because the perceptual-processing system tunes itself to exploit regularities of a typeface.\textsuperscript{164} As seen in figure 33 Gauthier et al. manipulated three different typefaces properties and obtained same-typeface advantages for one, the manipulation of aspect ratio that of size of ascenders or descenders, relative to x-height. Lowercase characters were used as is illustrated in figure 32 and 33 for these experiments. Lowercase is the regular practice in texts matter for reading. All uppercase characters have been found to be read slower than lowercase and are taught to be less legible this can be seen from Tinker and Paterson (1928) ‘Influence of Type Form on Speed of Reading’ giving results as follows:

<table>
<thead>
<tr>
<th>Type Form</th>
<th>Average No. Paragraphs Read</th>
<th>Difference in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower case</td>
<td>18.83</td>
<td>11.8\textsuperscript{165}</td>
</tr>
<tr>
<td>All capitals</td>
<td>16.61</td>
<td></td>
</tr>
</tbody>
</table>

Also in 1976 J. L. McClelland became a University Professor at Carnegie Mellon and held the Walter Van Dyke Bingham Chair in Psychology and Cognitive Neuroscience. He was a founding Co-Director of the Center for the Neural Basis of Cognition and has contributed to both the experimental and theoretical literatures in a number of areas, most notably in the application of connectionist/parallel distributed processing models to problems in perception, cognitive development, language learning, and the neurobiology of memory\textsuperscript{166} (cited by Sanocki-Dyson in ‘Letter processing and font information during reading: Beyond distinctiveness, where vision meets design’) where he presented the results of two experiments with 96 undergraduate students which showed that words with mixed uppercase and lowercase letters were perceived more accurately than mixed-case pseudo-words, and this research suggests that the negative effects of mixed letter case may arise because the difference in the size of uppercase and lowercase letter disrupt the grouping of letters into word units.

In the late 1960s and 1970s The Graphic Information Research Unit carried out research into a large part of British legibility and information design. This unit began as the Readability of Print Research Unit set up by Herbert Spencer at the Royal College of Art in 1966. Herbert Spencer (who was part of the unit till 1978) a designer, photographer, writer and editor along with Brian Coe (part of the unit till 1976) a typographer developed the unit and research along with Linda Reynolds a psychologist and information scientist. The initial funding was a two-year grant from the


\textsuperscript{165} Miles A. Tinker, Legibility of Print (Ames, Iowa, U.S.A.: Iowa State University Press, 1963), 57.

International Publishing Corporation (IPC). The IPC, comprised of the Mirror Group and several periodical and book publishers, which in 1970 was taken over by Reed International. The initial investigation was into the problem of legibility in ‘information publishing’ and was published in 1969 in *The Visible Word: problems of legibility* (Spencer 1969). The next contract/funding came from the Royal Mail with the brief to look into the legibility of telephone directories. In 1971 the unit was supported/funded by the Office of Scientific and Technical Information (OSTI) and this was later to become the British Library Research and Development Department. One of the major studies of legibility and readability of videotext display for the Royal Mail show that ‘The videotext and microform studies, although apparently technology-specific, had a much wider relevance, contributing as they did to on-going discussions about the influence of technology on the presentation of text.’167

Commonalities of type can also be exploited by the perceptual system. Letters within a set of type share similar parameters such as x-height or ascenders height because the parameters of a good typeface remain constant, and much of the perceptual information used for one word could be applied to subsequent letter processing, and because of this ‘letter-processing efficiency could be increased by tuning of the perceptual system’,168 so good constant design can help in the ‘getting used to’, understanding the text, thus helping with legibility.

A practical experience is an excellent guide in the selection of the material when researching into the legibility of typography for a specific purpose. Where research is complete on certain type this gives a starting point for further study especially when comparing existing typefaces to newly designed typefaces. C.Y. Suen and M.K. Komoda examined Letter Gothic, Courier and DECwriter typefaces. An outline of their experiments and results are outlined below. Dr. Ching Y. Suen is the Director of CENPARMI and the Concordia Chair on AI & Pattern Recognition. He received his Ph.D. degree from UBC (Vancouver) and his Master’s degree from the University of Hong Kong. He has served as the Chairman of the Department of Computer Science and as the Associate Dean (Research) of the Faculty of Engineering and Computer Science of Concordia University. Dr. Suen has published 4 conference proceedings, 12 books and more than 480 papers, and many of them have been widely cited while the ideas in others have been applied in practical environments involving handwriting


recognition, thinning methodologies, and multiple classifiers. Dr. Suen is the recipient of numerous awards, including the IAPR ICDAR Award (2005) and the ITAC/NSERC national award (1993).

C.Y. Suen and M.K. Komoda examined Letter Gothic, Courier and DECwriter fonts. Both upper and lower case letters were studied in two experiments to investigate the effect of font-style on legibility and on reading proficiency. …Further examination of the results points out the important aspect that while there is a tendency for some lower case letters to be more easily mistaken as their upper case counterparts, including c-C, o-O, s-S, u-U, v-V, w-W, x-X and z-Z in both Letter Gothic and DEC fonts; however, this trend does not occur in Courier. To the contrary, more upper case Courier letters were mistaken as lower case than the other way round including C-c, O-o, P-p, U-u, V-v, and W-w. These trends seem to have more to do with the design of the characters shapes in their respective fonts. …On the one hand, the results of Experiment 2 appear to be consistent with those obtained in Experiment 1. That is whether in terms of single letter identification or of the readability of text, DECwriter font produces the lower level of performance. Again, such results may not only be due to the dot-matrix of the font but also may be due to the lack of ascenders and descender elements within the font. On the other hand, the results of Experiment 1 and Experiment 2 are not entirely consistent. In Experiment 1, the Letter Gothic font was found to be more legible than the Courier font. However in Experiment 2, very little if any, difference was observed in the reading performance of texts presented into the two fonts. Thus, the reading skills and strategies brought to the reading situation can apparently attenuate the effects of the purely visual characteristics of the texts being read.\(^{169}\)

From this study, the question arises, how can you modify the shapes of some lower case letters so that the characters will not be mistaken as their upper case counterparts, for example, in the following characters, c-C, o-O, P-p, s-S, u-U, v-V, w-W, x-X and z-Z?

This 2001 study narrows down which typefaces work best for screen and at what point size. The following details came from Software Usability Research Laboratory Wichita State University website in relation to the 2001 study entitled ‘A Comparison of Popular online Fonts: Which are Best and Why’ by Michael Bernard, Melissa Mills, Michelle Peterson and Kelsey Storrer. The following typefaces types were compared: Agency FB (Agency), Arial, Comic Sans, Tahoma, Verdana, Courier New (Courier), Georgia, Goudy Old Style (Goudy), Century Schoolbook (Schoolbook), Times New Roman (Times), Bradley Hand ITC (Bradley), Monotype Corsiva (Corsiva). After a general survey of the Web it was found that the majority of sites used 12 point (pt) for much of the written content, using this along with the most popular typefaces at 12pt. The research team examined the difference in effective reading speed and also the perception of typeface legibility. The equipment used was a Pentium II based PC.

computer, with a 60 Hz, 96 dpi 17 inches monitor with a resolution setting of 1024 x 768 pixels. The typefaces were kept at 12 points except the Agency typeface, which was increased from 12- to 14-points in order to have a height (approximately 3 mm) that was comparable to the other typefaces. The test group consisted of twenty-two subjects, seven males and fifteen females aged between 20 to 44, and with a mean age of 25. All subjects had 20/20 unaided or corrected vision. 68% of them had at least four years in college and 95% regularly read documents on computer screens at least a few times per week. The subjects read twelve passages approximately the same length (an average of 1032 words per passage) with horizontal margins sat at 640 pixels, the typography was black on a white background.

The Process was as follows. Participants were positioned at a fixed distance of approximately 57 cm from the computer screen. They were then asked to read ‘as quickly and as accurately as possible’ the passages, which contained 15 randomly, placed substitution words (they were not told the number of substitution words). The substitution words, were designed to be clearly seen as inappropriate from the context of the passages when read carefully. These words varied grammatically from the original words—for example the noun ‘cake’ being replaced with the adjective ‘fake’. The participants were instructed to identify these words by stating the substituted words aloud. To accurately determine typeface legibility and its associated effect on reading time, an effective reading score was used. The score was derived from obtaining the percentage of accurately detected substituted words in the passages divided by the time taken to read the passages—which was registered by a stopwatch. After reading each passage, participants answered a perception of readability/aesthetic appeal questionnaire. The questionnaire consisted of a 6-point Likert scale with 1 = ‘Not at all’ and 6 = ‘Completely’ as anchors. When all twelve questionnaires were completed, they ranked the twelve typefaces for general preference. The conclusion of this study was as follows:

Several observations can be made regarding the examined font types. First, no significant difference in actual legibility between the font types were detected. There were, however, significant differences in reading time, but these differences may not be that meaningful for most online text because these differences were not substantial. It may, on the other hand, be helpful to consider using font types that are perceived as being legible. In this study, the font types that were perceived as being most legible were Courier, Comic, Verdana, Georgia, and Times.

The results of this study also provide information regarding the aesthetic appeal related to specific font types. For example, the ornate fonts Bradley and Corsiva were perceived as having a great deal of personality and elegance (However, one should be cautious in using these ornate fonts to any great extent
because of both their low performance and low popularity among the font types studied. Furthermore, Courier and Times were perceived as being the most business-like, whereas Comic was perceived as being the most fun and youthful.

Applying this information can help establish the proper mood of a particular site. For example, fonts that are perceived as being business-like and elegant may be more effective for a site such as an online bank. Conversely, fonts perceived as being youthful and fun, along with having personality, may be more effective for sites directed at children, such as an online toy store. Of course, general preference is an important consideration as well, especially for longer online passages. In this study, as well as our other font studies, Arial, Verdana, and Comic fonts scored high in preference.  

![Figure 34: Perceived typeface legibility (1 = ‘Not at all’ and 6 = ‘Completely’)](http://www.surl.org/usabilitynews/32/font.asp) Software Usability Research Laboratory Wichita State University (SURL) July 2001, Vol. 3 Issue 2.

![Figure 35: Percentage chosen as first or second preference choice.](http://www.surl.org/usabilitynews/32/font.asp) Software Usability Research Laboratory Wichita State University (SURL) July 2001, Vol. 3 Issue 2.

Conclusion

Research into the two concepts of readability and legibility are inextricably connected to the human action of reading. Readability is the ease with which the eye can absorb the message and move along the line. Legibility is based on the ease with which one letter can be distinguished from another. However, the research to date into the dual concepts of readability and legibility by adopting the positivist approach appears to have excluded or reduced to insignificance the variable factor involved in human introspection or intuition. The positivist approach adopted by the Modernist movement involves presuppositions that are based on objective reality, and that people/readers can identify this reality by symbols that can be accurately described and explained. But as Pyke in his 1926 research observes:

A fact eloquent to the fundamental trouble is already before the reader: *four times as many writers have measured legibility as have defined it.* Three out of every four writers have been attempting to measure something the exact nature of which they have not paused to examine.\(^{171}\)

Pyke concludes that: ‘Large typographical differences must be present before it is possible to say that there is any difference in the objective legibility of types.’\(^ {172}\) But any attempt to define legibility will not be a complete and accurate one if it excludes that variable factor or element involving the human action of reading in a natural setting. The human action of reading must take into account such factors that may impinge on it like, for instance, the subject being tired, hungry or even bored, and any typeface being studied for its legibility must take such factors into account. The connection between the dual concepts of readability and legibility and the human variable factor must be maintained when the effects of readability and legibility are being measured. Other factors involving the human element include age, sex, education or needing corrective aids for sight also impact on researches into readability and legibility. According to Zachrisson ‘it is advisable to relate legibility to a particular group of readers defined by age and experience’ for the following reasons:

- 11-year-old children read small type as fast and as well as larger sizes. Children as well as adults judge type and typography on the basis of wholeness rather than details.
- Our investigations suggest that it would be worthwhile to continue studies of the legibility of printed text and its congeniality value on different levels of reading maturity and of education, as well as with different content material.\(^ {173}\)

---

172 Ibid., p60.
With advances in technology it seems ‘that old theories and ‘rules’ concerning legibility are outdated’ yet Javal’s observation in the 1800s with the lower half of the word covered and the word is still legible still applies. Even though the technology is new it appears that ‘old theories’ and ‘rules’ concerning legibility have remained the same, and cannot be dismissed. Also, even though the technology for reading has changed the methods involving speed of reading and comprehension have remained the same. Tinker refers to this method of speed-reading ‘after reviewing all the literature in the field, that speed-of-reading performance is one of the most satisfactory methods for investigating legibility of print.’

Therefore, any new definition of readability and legibility to be relevant and accurate must make allowance for the human factor, and any new typefaces used with the new technology to be complete must also take into account established ‘old theories and ‘rules’, like, for instance, the method of speed reading which was hailed by Tinker as ‘one of the most satisfactory methods for investigating legibility of print.’

The findings and value of these studies has stood the test of time and have been revisited and confirmed other research for example the Miller & Bruner 1954 research “Familiarity of the letter sequences and tachistoscopic identification”: substantiated by Cattell’s 1885 findings on how the eye grasps words. This information is again being looked at by organisations like Microsoft (Advanced Reading Technologies team) to develop, improve and advance the case of legibility of text in the present day screen environment.

But in order to correctly assess reading and writing and legibility and readability one need to sample all ethnicities and levels and degrees of efficiency in reading i.e. a sample could not capture all the contributing factors and the facets or aspects of all typefaces.

---

176 Ibid., p23.
Chapter 4

Analysis and Recommendations

Introduction

The major aspects of legibility and readability were examined in chapters 1 and 2. The major research into these aspects was reviewed in chapter 3. The results of the examination in chapters 1 and 2 and the review in chapter 3 show that one major aspect of legibility, viz. the misreading of characters, has not been fully researched, especially, by way of comparative analysis, for example, Sanford found in his 1888 research that the orders of legibility differed and produced different results depending on the method used and he used three methods. Chapter 4 will demonstrate how further research into the misreading of characters by comparative analysis into the misreading of characters can identify factors, for instance, the character ‘Q’ is one of the most misread character. It also identifies which characters need redesigning and/or improving, based on the misreading rates of characters. It is therefore intended to demonstrate this unique discovery in this chapter by way of charts and comparative analysis based on available data regarding research into the misreading of characters, as Tinker stated ‘no single method of measurement is adequate for determining the legibility of print in all kinds of typographical setups.’ It is proposed in this chapter to present a comparative analysis of the foregoing research by the acknowledged authorities in the field of typographic research between 1888 to 1984. The research spanning this period deals with several changes in the reproduction of typography including, the invention of punch-cutting machine in 1885, phototypesetting or “cold type” in the 1950s, characters generated on a cathode ray tube with machinery and next computer aided typesetting in the 1960-1970s and the minicomputers-bases typesetting software introduced in the 1970s. It includes research not only into printed typography but also screen typography due to the major changes in the technology of presenting typography.

It may be useful at this stage to provide a summary of chapters 1, 2 and 3 before presenting the comparative research in this chapter. Chapter 1 showed that reading and writing developed over time with one purpose and that is to produce a system of translating sound in the spoken language to symbols and characters for the purposes of decoding them, and no matter what format the words took what was important was the meaning of

---

the words and to give readers what they demand, in other words, text that was legible and readable. There have been many alterations down through the centuries leading to the refinement of the system in use today resulting in the twenty six characters in the English alphabet, bearing in mind that writing must be understood, readable and legible. The spread of reading and the growth of literacy increased with the availability of reading material. This was due to several factors like ‘schooling and practice’ and the availability of reading material in a format that the reader wants, yet all reading depends on translating the symbols into the spoken language. The way we communicate with writing and text has changed over time but some trends stay the same. First came the refining down of the characters of the alphabet to twenty six, next came the division between words, marked by dots, triangular incisions or by ivy-leaf designs (hederae) then on to adding of word spaces and punctuation marks and also hyphenation and abbreviation of words.

Throughout the history of reading and writing one feature stands out and that is changing writing and characters to improve the comprehension of the symbols. This has lead to research into aspects of the written word all to the main aim to improve writing and by default reading. To find aspects that can be changed to aid in decode symbols of the spoken language.

Chapter 2 showed that the information about legibility and readability comes from two main methods. The first is from a practical application and a working knowledge of printing and typography. The second is the theoretical and analytical research carried out in laboratories under controlled scientific conditions which is looked at in chapter 3. Legibility is concerned with ‘typography and other physical aspects’. There is no definite answer to the question of legibility only ‘a desirable quality’, and it together with a combination of other elements give the reading public an easy read. The elements put together to achieve an easy read are the symbols that represent oral language for the purpose of the thesis is roman text and the English language. Chapter 2 also gives a short history of roman type as a background to legibility and readability, and also it explains the difference between the terms used to describe different aspects of the symbols used to represent the sounds in the spoken language: ‘type’, ‘roman type’, ‘alphabet’, ‘letters’ and ‘word’. Two of these terms, alphabet and letters are explained by Goudy — ‘The alphabet is a system and series of symbols representing collectively the elements of written language’ and ‘letters are individual characters that compose the alphabet, each being primarily a representative form’.

---

3 Frederic W. Goudy, Typologia (Berkeley, California, USA, University of California Press, 1977), 124.
4 Ibid., p.124.
The ‘typography and other physical aspects’ of typography when presented in different ways can produce either legible or illegible text, for example, the effect of colour on typography not only ink colour or characters on screen on coloured stock of coloured background but also the colour created by the counters, strokes and word and letter spacing. It is not just one element that controls legibility it is a combination of them, and also a combination of the elements for legibility research need to be taken into account to give a complete picture of legibility. The design elements of the individual characters along with the work layout of text contribute to an easy read or ‘a desirable quality’ for the reader to operate the symbols to translate oral language into written. Chapter 2 also deals with design aspects such as leading, point size, line length and colour.

‘Technology changes faster than design’ new typefaces are designed for new technologies but the design and knowledge of typography dates back to the 1400s. The human element had a very large say in design and because of this the human input cannot be removed from the equation. The reader has a large part to play in what is perceived to be and easy read, and habit of reading is an important aspect, the source material which is involved in developing habits in reading are designed and layed out by typographers and thus the typographer has a large affect on legibility working with the assumptions developed since the \textit{circa} 1450 and the invention of movable type. The human factor is totally engaged in typography and the working of the alphabet, and so accordingly, with the two concepts of legibility and readability. The typographic practitioner be he or she a typographer, layout designer, web designer or printer, all play a major role in the way we perceive legibility and readability and these two aspects determine what the reading public see and read. Different kinds of typography are designed for different jobs and with different conditions and it is not only the typefaces the makes a job legible it is as Ruari McLean stated the skill of the typographer designs the type piece to satify the needs of the reader the piece was designed for.

The findings of most ‘laboratory’ tests of legibility prove, if they prove anything, what suited those people, of that age and sex, at that time of day (tired? well fed? hungry? in good or bad temper?), in that month, in those conditions. But every job a typographer tackles is in a different set of conditions, and his skill is first to find out what those conditions are, and then to design particularly for them. The designer must always ask ‘what, why, who, when and where?’

Chapter 2 also shows different aspects of typography that affect legibility and these aspects must be noted in any research into legibility, as the arrangement of typography

\footnote{Ruari McLean, \textit{The Thames and Hudson Manual of Typography} (London: Thames and Hudson Ltd, 1997), 47-48.}
is the public face of typography and also the public face of what is or is not legible. The search for legibility encloses human interaction, and typographic contexts the public face of typography. Chapter 2 also illustrates aspects that need to be included when research into legibility is taken place. Several aspects in combination contribute to legibility, and thus a combination of research would present a more complete picture of legibility rather than one aspect being studied and presented as legibility. Zachrisson, as stated outlined factors that related to reading and these factors should be considered and included in future research to give a more complete rounded result.

1. **Reader.** Personality. Sex. Knowledge. Maturity (age, I.Q. etc.).
   Reading readiness and skill. Physical equipment.
2. **Text.** Purpose: Recreation or work-type. Length
3. **Typography and technical factors.** Appropriateness of technical means used.
4. **Situation.** Oral or silent reading. External conditions (lighting posture, environment etc.).

Chapter 3 outlines the criteria and methods of the acknowledged experts in the field such as E. C. Sanford, Albert Tinker, Louis-Émile Javal, James McKeen Cattell, Barbara Elizabeth Roethelein, Jean Anisson, Bror Zachrisson, Pyke and others. As stated Sanford (1888), Dockeray (1910), Tinker (1928), Bouma (1971), Geyer (1977), Banister (1927), Tinker (1928), Fisher et al. table 1 (1969), Townsend condition 1 (1971), Loomis (1982), Phillips et al. (1983) and van der Heijden (1984) are some of the leading published specialists in the field of misreading of characters. What is shown in chapter 3 is that the research into legibility and readability was mainly done in isolation or parallel research was conducted by the individual researchers, or was done in verification of existing research, for instance, Woodworth in 1948 confirmed the Erdmann–Dodge (1897) theory that reading takes place during the fixation-pause and that the eye sees little or nothing while moving, and in 1969 Smith confirmed Woodworth’s 1938 findings that word shape model is that lowercase text is read faster than uppercase text. Each piece of research has a particular value but a combination of several researches might have had the possibility of contributing a more complete picture or some unique piece of information.

Chapter 3 also outlines the factors used to study typography in legibility and readability with both printed typography and screen typography such as eye-movement and legibility, the visibility method, the distance method, the right type, the short-exposure method, the Focal Variator, the Blink test, speed of reading method and tests.

---

eye movement while reading. With the invention of computers and digital typography new research comparing printed text and text on screen included research into silent reading from screen versus paper. Also comprehension studies were carried out in relation to reading on screen versus paper, serif versus sans serif typefaces which is more legible and legibility of letter by comparing characters in the same typeface to identify misreading of characters.

The research into chapters 1, 2 and 3 has led to the discovery of a unique feature of legibility which has never being realised before, let alone researched, and this discovery has come about as a result of a comparative analysis of previous research into the misreading of characters. The research revealed that the letter ‘Q’ was the most misread letter by far of all the letters in the alphabet including case, i.e. U/lc (upper and lower case) and style (serif and sanserif), and which lead to the conclusion that ‘Q’ is the most misread letter in typography, and as a result ‘Q’ requires radical redesigning of the character to improve its legibility.

The results of the data and charts in chapter 4 support this unique discovery. The data consists of the rating of letters by misreading, and it was found by using statistical software, ie Microsoft Excel, that the letter ‘Q’ had a rating of 172.8 as opposed to the the rating of 96.2 for the ‘H’. This new discovery relating to ‘Q’ may be formulated and demonstrated by use of the following data and charts.

**Key to data and charts created to show a comparative analysis**
The research into misreading of characters and a comparative analysis is the subject matter of chapter 4. Data was presented in a ranking 1 to 32 and through this method of summerisation the resolution of the data was lost. The date lists the misread characters in order of misreading before a ranking was given there was no evidence of the difference in misreading of the characters in this research. By applying a different scale giving a frequency of 1 for the most misread character in each piece of research and 2 for the second most misread piece of research and so on to 32 for the least misread letter and compared or sorting the scale to different trends i.e. serif and sanserif and it was possible to presenting the data summery and detailed charts. This sort method is applied to the published research findings by Sanford (1888), Dockeray (1910), Tinker (1928), Bouma (1971), Geyer (1977), Banister (1927), Tinker (1928), Fisher et al. table 1 (1969), Townsend condition 1 (1971), Loomis (1982), Phillips et al. (1983) and van der Heijden (1984). Data is produced in tabular form showing the number 1 ranked for most misread letter, 2 ranked for character in second position of misread and so on down to
32 ranked for most misread letter for each piece of research from acknowledged experts, this is the accepted method in comparative analysis and statistical research, and the ranking is in tabular form a summation is given of the most commonly mistaken letter reviewed by case (i.e. U/lc).

Figure 36 is of a histogram of most commonly misread letters. Figure 36: Top three most common misread letters, Ranks 1-3 given equal weighting. Figure 39 shows the top three ranking compared with respect to serif and sans serif. Under the sub-heading common ground among most mistaken letters, figure 38 is a Pareto graph of top three misread letters (note a is unnaturally inflated (it is more with the t, g, e grouping), figure 37 shows top misread letters (a excluded for reason already stated) table 2: All data rated by order and split between cases and serif is presented by table 4. Table 5 presents all data with respect to higher (uppercase) and lower (lowercase), serif and sans serif. Figure 41 gives a Pareto review of all data, weighted according to ranking. Figure 42 gives a zoom on top of graph weighting according to rank. The chapter also investigates the shared features of characters and how the advances in technology in the way that characters are represented affect the reading of the characters. Chapter 4 concludes by advancing three major recommendations for further research into legibility.

**Summary Analysis of Misreading or Misrecognition of Characters**

The following information is a summary and analysis of all 5 Tables and generated for the purpose of a comparative analysis into the research of acknowledged authorities into misreading of type. The detail charts and tables follow this summary chart.

The summary table is compiled from the following charts and tables generated from the research on misreading as specified in Appendix Three. The information was sorted or compared by case, typeface style and by year. The following results come from sorting through the research findings on the most frequently misread letters both upper and lower case in Microsoft Excel for PC 2013 (print out of Excel file is found in Appendix Three). The sort includes ranking to weighting, by the inverse of rank and weight up to 26 (the letters in alphabet) and may result in increase resolution. The following is a review of the summary data (see Table 1). The information refers to the internal legibility of upper case and lower case (U/lc) individual characters, and not in groups of character either sense or nonsense groupings. The highest-frequency errors of misreading of characters are ranked 1. In some cases a rating is applied in order to improve the resolution of the analysis (* indicates where a rating is used i.e. Table 4).
<table>
<thead>
<tr>
<th>Table</th>
<th>Table 2</th>
<th>Table 3</th>
<th>Table 4</th>
<th>Table 5</th>
<th>Table 6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sort</strong></td>
<td>Upper/lower case (U/lc) Frequency score 1 most (misread = 1) (serif face = sf) (sans serif face = ssf)</td>
<td>Sorted by case Upper/lower case top eight misread characters (lowercase = lc) (Uppercase or caps = Uc)</td>
<td>Characters scored (100%) 1 frequency of 26 (26 — number of characters in the alphabet)</td>
<td>All 26 character rated by order, split between case, and serif and sans serif characters scored (100%) 1 frequency of 26</td>
<td>Misread characters by year of research and by occurrence ignoring case</td>
</tr>
<tr>
<td><strong>Findings</strong></td>
<td>a misread for n, u, s (1, sf), e misread for o (1, ssf) h misread for b (1, sf) l misread for i (1, sf) m misread for w (1, sf) q misread for o (1, ssf) q misread for g, o (1, ssf) t misread for i (1, ssf) y misread for p (1, sf) y misread for t (1, ssf)</td>
<td>Q misread in 5 studies (Uc) a misread in 3 studies (lc) l misread in 2 studies (lc) e misread in 1 study (lc) h misread in 1 study (lc) m misread in 1 study (lc) T misread in 1 study (Uc) y misread in 1 study (lc) and 1 study (Uc)</td>
<td>Scores for top 5 misread characters Q (Uc) 151.7 m (lc) 86.7 l (lc) 60.7 y (lc) 52.0 b (lc) 43.3</td>
<td>Top 10 ranked misread Q 172.8 H 96.2 E 96.0 L 93.0 F 92.9 M 85.0 Y 84.1 A 82.8 B 79.1 T 64.8</td>
<td>Top 10 misread by year Q 172.8 H 96.2 E 96.0 L 93.0 F 92.9 M 85.0 Y 84.1 A 82.8 B 79.1 T 64.8</td>
</tr>
<tr>
<td><strong>Comments</strong></td>
<td>Out of the rated 1 misread characters, nine fonts were serif fonts and seven fonts were sans serif fonts Q was misread for O in both serif and sans serif face, appeasers in 5 researches. A appeared in 3 researches</td>
<td>Top 8 misread characters were misread in 16 studies Q (only Uc) was the top misread character in 5 studies a (lc) was in second place but only appearing in 5 studies</td>
<td>Sans serif Q rated highest this was the only sans serif character in the top 5 misread character m, l, y and b were all serif fonts</td>
<td>Q rated highest (Uc) = 172.8 (139.2 = sans serif faces and 26.0 = serif faces) A rated highest (lc) = 81.3 lowest in (Uc) = 1.5 L rated second (lc) = 81.0 rated sixth lowest (Uc) = 21.1 X rated lowest (lc) = 5.4 rated eight (Uc) = 32.4</td>
<td>Sorting the information by year for the top ten misread characters. Thus it can be concluded that the advances in technology from 1888 till 1984 seem not to affect on the order of misreading of characters with difference in position 23 and 24</td>
</tr>
</tbody>
</table>

**Table 1:** Summary of findings in chapter 4.
Detailed Analysis of Misreading or Misrecognition of Characters

As can be seen from the Excel file in Appendix Three there are no details other than researcher, year, typeface actual letter misread, mistaken letter character, test method and if the character was either upper or lower case. For the purpose of this analysis no detailed information is given on the demographic tested, i.e. the screening of the test subjects of eyesight, age, competence of reading and other possible factors that could lead to mistakes. Also, it is not known whether the test subjects were surveyed like for like, i.e. of the same age group, level of education or equal eyesight? These factors need to be accessed and recorded to ensure the validity of future data. In some cases a rating is applied in order to improve the resolution of the analysis (* indicates where a rating is used) and any assumptions used are explained below.

<table>
<thead>
<tr>
<th>Upper/lower case</th>
<th>Researcher</th>
<th>Year</th>
<th>Test method</th>
<th>Type face</th>
<th>Actual letter</th>
<th>Mistaken for</th>
<th>Frequency score (1 high, high number lower ranking)</th>
<th>Serif/sans serif</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower</td>
<td>Dockery</td>
<td>1910</td>
<td>Panifoveal vision</td>
<td>Old style roman</td>
<td>a</td>
<td>n</td>
<td>1 Serif</td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>Dockery</td>
<td>1910</td>
<td>Panifoveal vision</td>
<td>Old style roman</td>
<td>a</td>
<td>u</td>
<td>1 Serif</td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>Dockery</td>
<td>1910</td>
<td>Panifoveal vision</td>
<td>Old style roman</td>
<td>a</td>
<td>s</td>
<td>1 Serif</td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>Geyser</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>e</td>
<td>o</td>
<td>1 Sans serif</td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>b</td>
<td>1 Serif</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>Booma</td>
<td>1971</td>
<td>Distance</td>
<td>Courier</td>
<td>t</td>
<td>i</td>
<td>1 Serif</td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>Booma</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>l</td>
<td>i</td>
<td>1 Serif</td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>m</td>
<td>w</td>
<td>1 Serif</td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>Townsend condition</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>q</td>
<td>o</td>
<td>1 Sans serif</td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>q</td>
<td>g</td>
<td>1 Sans serif</td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>q</td>
<td>o</td>
<td>1 Serif</td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>Loomis</td>
<td>1962</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>q</td>
<td>o</td>
<td>1 Sans serif</td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>q</td>
<td>o</td>
<td>1 Sans serif</td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>Fisher et al. table 1</td>
<td>1969</td>
<td>Short exposure Futura medium</td>
<td>t</td>
<td>i</td>
<td>1 Sans serif</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>y</td>
<td>p</td>
<td>1 Serif</td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>distance</td>
<td>Helvetica</td>
<td>y</td>
<td>t</td>
<td>1 Sans serif</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Data showing the number 1 ranked misread letter.

*Note ‘a’ was only identified in one study for the rating 1, where as ‘Q’ was identified across a number of studies. From this it can be assumed that Q (uppercase only) is the lead letter. As Q looks the same as O without the tail this is not an unexpected.*

From the above table it can be seen that the data indicates that in the misread lower case (lc) characters, i.e. characters without ascenders and descendes, have been misread, for instance, a for n, u, s and e for o, and m for w. The next aspect of note is that characters with an ascender have been mistaken for characters with ascenders h for b and l for i (the dot over the i is to be found in the ascender section of the characters), and also the characters that have the same character width. For the uppercase characters, it seems
that characters with the same basic shape have also been mistaken for each other, for instance, G, O, with Q, as these three characters are all based on an oval shape, and Y with P and T, as these characters are top heavy standing on a straight trunk, T and I are both vertical shapes parts and do not seem to share the same width as T has arms at the top of character.

In uppercase only, Q is mistaken in most cases for O, and also G in one out of the five recorded occurrences of misread characters. The reason for this could be the characters same overall oval shape, width and height.

<table>
<thead>
<tr>
<th>Count of Actual letter</th>
<th>Column Labels</th>
<th>Grand Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row Labels</td>
<td>Upper case</td>
<td>Lower case</td>
</tr>
<tr>
<td>A</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>E</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>H</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>L</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>M</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Q</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>T</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Y</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>7</strong></td>
<td><strong>9</strong></td>
</tr>
</tbody>
</table>

*Table 3:* Summation of the most commonly mistaken letter reviewed by case (i.e. U/lc).

![Histogram of most commonly misread letters](image)
Note ‘a’ was only identified in one study for the rating 1, whereas ‘Q’ was identified across a number of studies. From this it can be assumed that Q (uppercase only) is the lead letter (most misread character).

We will expand this simple analysis of the summary data presented in Sofie Beier’s 2012 publication *Reading Letters designed for legibility*.

Figure 6.1: The most frequently misread lowercase letters and Figure 6.2: The most frequently misread uppercase letters to the top 3 letters and look for more trends and indications. As the difference in actual occurrences that lead to the ranking is unknown (by working on summary data) the top three letters given equal weighting is a valid assumption.

![Graph showing misread letters](image)

**Figure 37:** Top three most common misread letters, Ranks 1-3 given equal weighting.

By limiting the analysis to the top three letters 20 of the 26 letters are captured, i.e. 4/5 of the alphabet. ‘A’ seems to get 3 points, but it should be noted that this was only in one study and should again be ignored as a leading misread character. The most noticeable trend that developed is Q (in uppercase only) followed by a group containing b, f, l, j, and m.

What do these characters have in common? Again it is possible that the basic shapes and proportions (i.e. width and height) of the character are similar and could cause misreading. The other thing to observe here is that even though Q is the leading letter it is only misread in the uppercase and does not show up in the lowercase of the top 3. M, m and J, j and F, f and B, b, are now misread in the upper and lower.

---

Note ‘a’ was only identified in one study for the rating 1, where as ‘Q’ was identified across a number of studies. From this it can be assumed that Q (uppercase only) is the lead letter (most misread character).

**Figure 38:** Pareto of top three misread letters (note a is unnaturally inflated (it is more with the t, g, e grouping).

Group 1 (high): Q, m, a, l, y, b. Group 2 (medium): h, j, f, e, T, g. Group 3 (low): c, i, P, V, X, O, w. Do the characters in each group have anything in common? The three groups have very little in common, group 3 is predominantly uppercase, and the other two groups are mainly lowercase. One interesting fact is that Q as the lead misread letter has been mistaken for O in three studies, but O is in the low group for misreading of the top three rated misread characters.

Table 4 shows that the lowercase b has been misread as h for both serif and sans serif, and again the probable reason is that the characters have the same basic shape and proportion. It is possible that the character lowercase m may be mistaken with the basic shapes of n for the curve joined to the upright strokes, and here it cannot be said that m was mistaken for a character of same proportions, and m could have been misread for both upper and lowercase w because of the repeat shape. Uppercase M is mistaken for uppercase U in the sans serif, although they do not have the same shape they have similar width, and they do not seem to have any other common elements to explain the misreading.
<table>
<thead>
<tr>
<th>Upper/lower case</th>
<th>Researcher</th>
<th>Year</th>
<th>Test method</th>
<th>Type face</th>
<th>Actual mistaken letter</th>
<th>Mistaken for</th>
<th>Frequency score (1 high, high number lower ranking)</th>
<th>Serif/sans serif</th>
<th>Score (100%)</th>
<th>Total score for the letter.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower</td>
<td>Dockerery</td>
<td>1910</td>
<td>Parfoveal vision</td>
<td>Old style roman</td>
<td>b h</td>
<td>2 Serif</td>
<td>13.0</td>
<td></td>
<td></td>
<td>43.3</td>
</tr>
<tr>
<td>Lower</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>b h</td>
<td>3 Serif</td>
<td>8.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>b h</td>
<td>3 Sans serif</td>
<td>8.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>Townsend condition 2</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif Futura</td>
<td>b r</td>
<td>2 Sans serif</td>
<td>13.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Distance</td>
<td>Courier</td>
<td>l i</td>
<td>1 Serif</td>
<td>26.0</td>
<td></td>
<td></td>
<td>60.7</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>l i</td>
<td>1 Serif</td>
<td>26.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>l i</td>
<td>3 Serif</td>
<td>8.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Distance</td>
<td>Courier</td>
<td>m n</td>
<td>3 Serif</td>
<td>8.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>m u</td>
<td>2 Sans serif</td>
<td>13.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>m w</td>
<td>1 Serif</td>
<td>26.0</td>
<td></td>
<td></td>
<td>86.7</td>
</tr>
<tr>
<td>Upper</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>distance</td>
<td>Helvetica</td>
<td>m w</td>
<td>2 Sans serif</td>
<td>13.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>q g</td>
<td>1 Sans serif</td>
<td>26.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>q o</td>
<td>1 Sans serif</td>
<td>26.0</td>
<td></td>
<td></td>
<td>151.7</td>
</tr>
<tr>
<td>Upper</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>q o</td>
<td>1 Serif</td>
<td>26.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>q o</td>
<td>1 Sans serif</td>
<td>26.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>q o</td>
<td>1 Sans serif</td>
<td>26.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>Fisher et al. table 2</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>q o</td>
<td>2 Sans serif</td>
<td>13.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>q o</td>
<td>3 Sans serif</td>
<td>8.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>y p</td>
<td>1 Serif</td>
<td>26.0</td>
<td></td>
<td></td>
<td>52.0</td>
</tr>
<tr>
<td>Upper</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>distance</td>
<td>Helvetica</td>
<td>y t</td>
<td>1 Sans serif</td>
<td>26.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Top misread letters (a excluded for reason already stated)."
Figure 39: Top three ranking compared with respect to serif and sans serif.

The data indicates that the upper and lowercase b and m are equally misread at the same level in serif and sans serif. Also the data indicates that the upper and lowercase s and y are equally misread at the same level in serif and sans serif. In both of these cases the basic shapes of the upper and lowercase characters are very similar: B and b, M and m, S and s and Y and y. But the basic shapes of the upper and lowercase characters are very similar for C, c and X, x, yet x had misreading in sans serif and not in serif, and c had misreading in serif and not sans serif in figure 29 (note ‘a’ was only identified in one study for the rating 1).
Table 5: All data rated by order and split between cases and serif.*

Note ‘a’ was only identified in one study for the rating 1, whereas ‘Q’ was identified across a number of studies. From this it can be assumed that Q (uppercase) is the lead letter.

![Figure 40](image_url)

Figure 40: All data with respect to upper case and lower case, serif and sans serif.
Figure 41: Pareto review of all data, weighted according to ranking (U = upper case, lc = lower case).

Figure 42: Zoom of figure 41 showing detail of top eleven characters weighting according to rank (U = upper case, lc = lower case).

It seems from the data that the uppercase q is the more misread character sans serif and then in order e, h, l and f about the same, m and y about the same, next a, b, t and c are the top eleven ranking misread characters. But as been noted ‘a’ was only identified in one study, where as ‘Q’ was identified across a number of studies. From this it can be assumed that Q is the lead letter.
Table 6: All data sum of inverse rating by year and occurrence ignoring case.*

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>q</td>
<td>2.5</td>
<td>1.9</td>
<td>36.0</td>
<td>27.9</td>
<td>14.0</td>
<td>28.2</td>
<td>1.4</td>
<td>26.8</td>
<td>3.1</td>
<td>31.2</td>
<td>172.8</td>
</tr>
<tr>
<td>h</td>
<td>19.8</td>
<td>7.4</td>
<td>3.8</td>
<td>36.7</td>
<td>1.2</td>
<td>9.6</td>
<td>7.4</td>
<td>10.4</td>
<td>96.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e</td>
<td>4.2</td>
<td>26.0</td>
<td>6.5</td>
<td>3.5</td>
<td>11.6</td>
<td>32.5</td>
<td>2.0</td>
<td>4.4</td>
<td>5.2</td>
<td>96.0</td>
<td></td>
</tr>
<tr>
<td>l</td>
<td>16.4</td>
<td>7.8</td>
<td>3.9</td>
<td>4.8</td>
<td>55.7</td>
<td>2.8</td>
<td>1.7</td>
<td>93.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f</td>
<td>3.7</td>
<td>15.6</td>
<td>1.5</td>
<td>15.3</td>
<td>9.4</td>
<td>11.0</td>
<td>17.4</td>
<td>3.7</td>
<td>8.7</td>
<td>6.5</td>
<td>92.9</td>
</tr>
<tr>
<td>m</td>
<td>32.4</td>
<td>5.2</td>
<td>4.0</td>
<td>12.0</td>
<td>16.5</td>
<td>13.0</td>
<td>2.0</td>
<td>85.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>y</td>
<td>31.8</td>
<td>1.2</td>
<td>4.3</td>
<td>5.3</td>
<td>2.5</td>
<td>1.7</td>
<td>8.6</td>
<td>28.6</td>
<td>84.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>78.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>82.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>6.5</td>
<td>13.0</td>
<td>2.4</td>
<td>9.5</td>
<td>22.9</td>
<td>8.7</td>
<td>5.7</td>
<td>6.5</td>
<td>4.0</td>
<td>79.1</td>
<td></td>
</tr>
<tr>
<td>t</td>
<td>6.6</td>
<td>1.5</td>
<td>2.4</td>
<td>8.6</td>
<td>26.0</td>
<td>9.9</td>
<td>5.9</td>
<td>1.1</td>
<td>2.9</td>
<td>64.8</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>2.8</td>
<td>17.3</td>
<td>3.8</td>
<td>9.6</td>
<td>4.0</td>
<td>14.8</td>
<td>5.5</td>
<td>2.4</td>
<td>60.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i</td>
<td>22.2</td>
<td>9.8</td>
<td>6.1</td>
<td>3.3</td>
<td>9.5</td>
<td>5.2</td>
<td>2.0</td>
<td>58.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>4.3</td>
<td>6.5</td>
<td>2.3</td>
<td>1.7</td>
<td>28.9</td>
<td>4.4</td>
<td>3.8</td>
<td>51.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>j</td>
<td>15.6</td>
<td>5.8</td>
<td>14.0</td>
<td>8.7</td>
<td>6.0</td>
<td>1.3</td>
<td></td>
<td>51.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>o</td>
<td>4.1</td>
<td>2.2</td>
<td>3.7</td>
<td>1.7</td>
<td>7.6</td>
<td>3.4</td>
<td>10.1</td>
<td>2.1</td>
<td>7.3</td>
<td>42.3</td>
<td></td>
</tr>
<tr>
<td>w</td>
<td>10.0</td>
<td>1.3</td>
<td>4.6</td>
<td>3.7</td>
<td>7.5</td>
<td>1.2</td>
<td>3.3</td>
<td>7.2</td>
<td>38.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>6.5</td>
<td>3.5</td>
<td>3.3</td>
<td>7.2</td>
<td>1.6</td>
<td>7.1</td>
<td>2.5</td>
<td>5.2</td>
<td>1.6</td>
<td>38.4</td>
<td></td>
</tr>
<tr>
<td>x</td>
<td>2.5</td>
<td>3.2</td>
<td>5.0</td>
<td>6.5</td>
<td>3.2</td>
<td>1.0</td>
<td>2.5</td>
<td>14.0</td>
<td>37.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>s</td>
<td>1.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>34.6</td>
<td></td>
</tr>
<tr>
<td>p</td>
<td>3.7</td>
<td>2.0</td>
<td>1.0</td>
<td>14.3</td>
<td>1.4</td>
<td>1.2</td>
<td>2.4</td>
<td>4.3</td>
<td>1.2</td>
<td>2.0</td>
<td>33.5</td>
</tr>
<tr>
<td>k</td>
<td>3.3</td>
<td>4.4</td>
<td>4.4</td>
<td>4.0</td>
<td>5.9</td>
<td>0.9</td>
<td>6.0</td>
<td>3.3</td>
<td>32.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>v</td>
<td>2.9</td>
<td>1.4</td>
<td>13.0</td>
<td>1.4</td>
<td>3.3</td>
<td>1.1</td>
<td>3.3</td>
<td>3.7</td>
<td>30.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>3.3</td>
<td>4.7</td>
<td>8.0</td>
<td>8.0</td>
<td></td>
<td>4.3</td>
<td>0.9</td>
<td>1.4</td>
<td>22.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>z</td>
<td>1.2</td>
<td>1.1</td>
<td></td>
<td>11.1</td>
<td>5.0</td>
<td>1.0</td>
<td>2.7</td>
<td>22.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d</td>
<td>2.1</td>
<td>2.6</td>
<td>4.3</td>
<td>3.3</td>
<td>1.9</td>
<td>2.1</td>
<td>16.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>u</td>
<td>1.4</td>
<td>4.7</td>
<td>1.5</td>
<td>3.7</td>
<td></td>
<td></td>
<td>0.8</td>
<td>12.2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Does the order of misreading of characters change when the information is sorted by year, and thus does the order of misreading change with the changes of technology from 1888 (that is from Sanford’s research) to present day technology for presenting text? When the misread letters are sorted by year q comes out on top as with the sort by ranking. The letter a now comes out in eight place and as a was only included in one study this seems to be a more accurate position, especially when the amount of time for each character in all the research is taken into account. The top hitters when the year of the research is taken into account are as follows: q, h, e, l, f, m and y differ when the year is not taken into account q, h, e, l, f, m and y. Where the difference in rating is by year and frequency 23 and 24 are at the end of the least misread characters (26 the least misread and 1 the most misread). The character z is in position 23 when using the frequency score (1 high (top of misreading character), high number lower ranking) but z
is in position 24 rated misread rated occurrence by year of study, while n is in position 23 by frequency score and position 24 rated occurrence by year of study. The lowest five misread characters are from lowers up, u, d, z, n and the fifth lowers letter is v.

**Figure 43:** All data rated by year not showing case.

**Figure 44:** Zoom of figure 43 showing detail of top ten characters misread letters by year not taking case into account, the characters are as follows but not in order – u, d, z, n, v, k, p, s, x, r.
When the year is included it may be asked: Have advances in technology in the way that characters are represented affect the reading of the characters?

The advances in technology for the seventeenth century onwards do not seem to have had any significant affect on the misreading of characters, Sanford’s 1888 results were these findings were for the lower case characters.

Order of time: m w d p v y j p k f b l i g h r t o u a n e s c z
Order of distance: w m p q v y j f h r d g k b x l n u t i z o c s e.

Figure 45: Pareto review of all data, sum of inverse rating viewed by year.

Figure 46: Review of all data, by year.

---

Figure 47: Top seven misread characters by year.

Figure 48: Top misread characters per year (U = upper case, lc = lower case).
Figure 49: Frequency of misread letters, including upper/lower case and total, per year (U = upper case, lc = lower case).

Lowercase d is the only character that is not misread in all of the studies reviewed here (see table 4 above). In the overall chart the character d is given a rating of 26 as being the lower letter in the chart. All other characters are misread in upper and lowercase. From Sofie Beier’s charts it can be observed that only in two studies Bouma’s 1971 study of misread lowercase characters a is misread as d, and in Tinker’s 1928 study of misread lowercase characters q is misread as d. From this it seems that lowercase d is the most identifiable character of all upper and lowercase characters. The lowercase d is not listed in the chart for the Sanford 1888 study as can be seen from Appendix 3 Sanford entries. Referring to Sanford’s original paper lowercase d features for the example in Sanford’s ‘Table 1: Results by the first method for distance order of letters as shown by percentages of right answer’, d is in thirteenth position with 68.3%.10 and in Sanford’s 1888 results lower case d is listed third in the order of time for misreading.

| Order of time | m w d p v y j p  k f b l i g h r x t  o u a n e s c z |
| Order of distance | w m p q v y j f  h r d g k b x l n u  t i z o c s e.11 |

---

Conclusion
There is extensive research and study into typography, reading, writing, legibility and readability since the invention of writing and all to one purpose, i.e. to make type easier to read. The identifying of characters for the purpose of decoding them is a vital part of working this system i.e. reading and writing. Reading and writing ‘require schooling and practice, the deliberate shaping of the brain’. 12 And yet after all the years that go into learning the system there is still misreading of characters. Chapter 4 has illustrated in table 6 that including the year of research the order of legibility changes only in the least misread characters, and from this it may be concluded that the changes in technology have had little or no effect on the legibility of characters. As already stated the research in chapters 1, 2 and 3 led to the discovery of a unique aspect of legibility which was never being truly realised before, let alone researched, that as a result of a comparative analysis of previous research into the misreading of characters, it is apparent that the letter ‘Q’ is the most misread letter by far of all the letters in the alphabet. The results of the data and charts in chapter 4 support this rather unique discovery, that the letter ‘Q’ had a rating of 172.8 as opposed to the rating of 96.2 for ‘H’ the second most misread character. By concluding that the shape of the characters and their similarity to others characters is the reason for this misreading would indicate that the design of the character needs to be altered to diminish or put an end to this misreading of letters, starting with Q the most misread letter of all.

As well as being the most the most misread letter of the alphabet Q is also the least used letter in the English language. This is also the case in languages such as Polish, Dutch, German, and even Turkish. However, in languages such as French, Italian and Spanish which are all based on the Roman (or Latin) alphabet, the letter Q is in frequent use, and that in itself is indicative of the need for further research into the design of the letter Q. Even though the letter Q is less frequently used in, say, the English language, does not necessarily mean that it should not be re-designed to make it more readable. Therefore, it is its enhanced readability, and not its frequency of use, that provides a sufficient enough reason for its re-design.

**Recommendations for Further Research**

1. The complete findings in the various researches should be cross referenced to get a more accurate findings by using statistical software, such as Minitab, a software that is accepted as the industrial standard. This should give a more accurate view of letters/characters that are misread the most.

2. Researchers into legibility seem to work in isolation and refer to other legibility research as historical background only. The existing research does not seem to have been cross-referenced to take note of any common trends for the purposes of furthering that research. Although in 1954 Miller & Bruner did substantiate Cattell 1885 findings and showed that the eye could grasp the whole word as quickly as a letter, and that sense material or sense words are read at a greater speed than nonsense material. But this seems to be the exception rather than the rule. Legibility research seems to have been conducted by researchers who were concerned only with presenting their own views in isolation from each other, and failed to take into account the previous research by others in the same area. Current legibility researchers should therefore take a more collegiate approach to their research by referring to the research of their contemporaries in the field, and also by taking note of the research of former researchers into legibility (which is extensive see Appendix One).

3. The following typographical features are generally recognised as supporting a better legibility: larger x-height, open counters (counters: spaces partly or fully enclosed by the letterform), serifs and oblique stoke axis. Legibility is the ease of deciphering individual characters. It is about perception, and is affected by design attributes such as the foregoing typographical features considered as supporting better legibility and based on knowledge acquired through centuries of practice. Larger x-height for continuous text assists in making the counters more perceptible. Serifs are believed to support the eye movement along the line of text, to make for more distinctive letterform, and they usually belong to letterforms with thicks and thins.\(^{13}\) Greater research should be conducted into the typographical features of legibility and the knowledge and practice that gave rise to them down through the centuries.

---

Bibliography


The Journal Of Typographic Research. Volume III, Number 2, April 1969, Journal, c/o The Cleveland Museum of Art, Cleveland Ohio, USA.


Trumangray, Clarence, Types of Reading Ability, as Exhibited through tests and laboratory experiments an investigation subsidized by the General Education Board (First published 1917, reprint 2013 in India by Isha Books, B-69, New Gupta Colony, New DDA Market, New Delhi – 110009).


**Website**


Cattell, James McKeen, (1887), Classics in the history of Psychology – Cattell (1887)
An internet resource developed by Christopher D. Green, York University,
Toronto, Ontario. ‘The Time Taken Up by Cerebral Operations’, James McKeen
Cattel (1887), Assistant in the Psychological Laboratory, University of Leipsic.
Chamberlin, Jamie. American Psychological Association, Questionnaire ‘Type cast –
Microsoft psychologist Kevin Larson teams with typographers and computer
engineers to improve our ability to read onscreen’, November 2012, Vol 41, No.
10, Print version: Page 28, Accessed February 18, 2013. Pdf available:
Chandler, Scott Bondurant. ‘Legibility and Comprehension of Onscreen Type’
http://scholar.lib.vt.edu/theses/available/etd-11172001-
Chapman-Cook Speed of Reading Test, http://scholar.lib.vt.edu/theses/available/etd-
Cherry, Kendra, ‘Edward Thorndike Biography (1874-1949)’,
May 16, 2014.
Cherry, Kendra, ‘What Is the Law of Effect?’,
http://psychology.about.com/od/profilesmz/p/edward-thorndike.htm Accessed
May 16, 2014.
Dionysius Thrax, NNDB Tracking the entire world. Available on
designers wish they could learn from research’. Available on:
July 3, 2014.
Dyson, Mary C. ‘The role of fonts in reading’ PowerPoint at Reading University,
Dyson, Mary C. & Haselgrove, Mark ‘The influences of reading and line length on the
effectiveness of reading from screen’. Available at:
Gauthier, Isabel, Wong, Alan C-N., Hayward, William G., Cheung Olivia S., ‘Font tuning associated with expertise in letter perception’ Perception, 2006, volume 35, pages 541–559, DOI:10.1068/p5313, Department of Psychology, Vanderbilt University, Wilson Hall, Nashville, TN 37203, USA; e-mail: isabel.gauthier@vanderbilt.edu; Department of Psychology, University of Hong Kong, Pokfulam Road, Hong Kong, Received 16 June 2004, in revised form 24 May 2005; published online 15 March 2006.


Glossary

**Ascender** — a section of a lower case letter that extends above the x-height for example the upper part of the characters l, f, t, h, b, d or k.

**Algorithms** — a set of steps that are followed in order to solve a mathematical problem or to complete a computer process.

**Alphabet** — a set of characters used to write or print one or more languages.

**Baseline** — an imaginary line on which the base of capitals rest or characters without descenders.

**Binary digits** — also known as ‘bit’ is the smallest unit of data in a computer. A bit has a single binary value, either 0 or 1.

**Blink test** — the blink test records the number of blinks over a set period, for typography this would be reading different fonts size over a set period and take not of the number of blinks — the more blinks the harder the task or the less legible the font. Normal blink rate is about 20 blinks per minute, although there are wide variations and this frequency is reduced by as much as 7.5 blinks per minute when you are concentrating on your computer screen and digital type.¹ Luckiesh and Moss’s research (1947) used the following method: for a period of five minutes the subject read continuous text printed in sets of different point sizes, for example, text set in 6-point type and 12-point type, and the eye blinks were counted by direct observation for the test period. Several subjects were tested, and the test was repeated for each subject in different sequences.

Conditions were kept constant for all the subjects and the data for the subjects were averaged.

**Book** — any written work consisting of leaves bound permanently together.

**Book face** — is an old term for a particular typeface, but now used to mean any typography suitable for the text of a book.

**Bouma shape** — bouma is the shape formed by the outline of a word. Words are recognised by their shape. The psychologists call this image the *Bouma shape* based on the Dutch psychologist Herman Bouma who researched word-shape-based reading. In the following diagram the outline shape or the tinted shape illustrates the bouma shape.

**Bowel** — the enclosed space in characters such as in o and a.

**Cathode ray tube (CRT) screen** — a vacuum tube used as a display screen in a computer monitor or TV. The viewing end of the tube is coated with phosphors, which emit light when struck by electrons.

**Cap height** — the height of a capital letter.

**Codex** — a book form where sheets which are not pasted or stitched together to form a long roll but are superimposed on each other folded across the middle, and then secured by stitching so that they open into pages. The outside pages can be protected by binding covers and the whole ensemble then forms a durable, sturdy
book, easy to store, easy to open and refer to, easy to carry about, and uses both sides of the writing material.

**Colour of type** — the light or heavy appearance of a particular typeface. When the same text is printed in the one colour (for instance, black) but different weight typefaces are used so that the heavy strokes will look blacker than the fine strokes of the typeface or lighter versions of a typeface, ‘the fine lines looks grey and a number of them together make a grey surface. The same type size looks different according to the spacing of the letters and the varying distance between the lines.’ See Chapter 2, figure 10, page 38.

**Counter** — is the inside area of the typeface e.g. the centre of a c or the space between the vertical strokes of m, n, v.

![Counter Diagram](image)

**Column** — is a section of a page divided vertically, and which contains text, images or other matter. A column is measured by its horizontal width or line length.

**Compositor** — the person responsible for setting type either by hand or machine process.

**Continuous textual material or continuous text** — the classification of prose into sentences and organised by paragraphs. Organisation occurs by paragraph setting, indentation, and the breakdown of text by headings that help the reader to recognise the organisation of the text. The primary classification of continuous texts is by rhetorical purpose or text type. These include expository, descriptive, argumentative and injunctive.

**Copyist** — a copyist is a person or transcriber who makes or imitates copies.

**Cuneiform characters** — these are wedge-shaped characters used in ancient Assyrian, Babylonian and Persian inscriptions. Cuneiform is a system of writing first invented and developed by the ancient Sumerians of Mesopotamia c. 3500-3000 BCE. The name comes from the Latin word *cuneus* for ‘wedge’ owing to the wedge-shaped style of writing.

---

Descenders — in typography, a descender is the portion of the letter in a Latin alphabet that extends below the baseline of a font. For example, in the letter y, the descender would be the “tail,” or that portion of the diagonal line, which lies below the ‘v’ part of the letter ‘y’.

Display fonts or type — these are the larger typefaces designed to attract attention used for headlines, usually above 14pt in bookwork.

Distances method — this method requires the characters to be read and positioned at different distances from the reader/subject.

Doubling — reading a line of text twice.

Focal Variator — a method used only to identify the legibility of individual characters or single words. Invented by A. P. Weiss in 1917. The focal variator is a system of lenses arranged to each other to produce a visual stimulus (in the case of typed – printed copy), and is projected upon a ground glass screen with different degrees of clearness from an unrecognisable blur to clear crisp focus, and by doing so the different degree of focal can be measured and recorded. The lenses are interconnected in such a way that they travel in opposite directions: one lens increases the type, the other reduces the size of the type. The focal variator controls the degree to which characters and letters may be thrown out of focus, and so it can be determined when the characters remain distinguishable.

Font — formerly called a fount, i.e. a complete supply of a typeface.

Font tuning — a reader can tune into one specific typeface and thus read it. ‘Font tuning (FT) occurs when observers recognize a sequence of letters presented in the same font faster than in different fonts’.

Font hinting — hinting was originally developed for low-res printers (a 300-600 dpi laser printer is a low-resolution device), but used also for on-screen rendering.

---

“Hinting” refers to methods that guide grid fitting of continuous glyph outline onto a discrete grid, such as these found on a display screen or laser printer. Scalable outline fonts – such as fonts in Adobe Type 1 and TrueType format – have continuous shapes described by mathematical curves. These are used to create a discrete raster of dots on a display or hardcopy device at a specified size. If such a bitmap is made in a simplistic way – such as simply blackening each cell whose centre lies within the contours – then a number of visually distracting artifacts arise – such as misalignments of feature and breaks in shapes, also called ‘drop-outs’. Hinting is used to do such things as: make sure stems intended to be equally thick appear equally thick, suppress overshoots – rounded letters (O) are taller than flat ones (X), line up features on different glyphs that should be the same height, avoid ‘drop-outs’, keep counters between stems open, force consistent spacing between sets of parallel strokes, and compensate for ‘misfeatures’ of the rasterization algorithm such as drop-outs.\(^6\)

![Figure 1a. An outline that hasn't been grid-fitted. Note how poorly the outline corresponds to the pixel pattern, and above all how awkward the bitmap of the M is.](image1)

![Figure 1b. The same outline grid-fitted. Now the outline has been adjusted to fit snugly around each pixel, ensuring that the correct pixels are turned on.](image2)


**Glyphs** — in information technology, a glyph (pronounced GLIHF ; from a Greek word meaning carving) is a graphic symbol that provides the appearance or form for a character. A glyph can be an alphabetic or numeric font or some other symbol that pictures an encoded character.

**Gutters** — this is a term used in the imposition for the space made up of foreedges of pages plus the trim.

**Hangul** — a system of writing invented by King Sejong of Korea in 1446 AD which he moved away from the Chinese system of writing and introduced twenty-eight letters which were easier to learn and use, and called his system ‘Hangul’.

**Hederae** — a space-filling intra-word character. Words in inscriptions were frequently separated by an ivy-leaf-like decoration design. These *hederae* were placed not at the bottom of a line, as with our full stops, but were set halfway up the height of the letters.

**Hieroglyphics** — a hieroglyphic is a stylised picture of an object representing a word, syllable, or sound.

[Image: Egyptian hieroglyphics]

**HyperCard** — HyperCard is an early (1986) Macintosh application that enables users to author hypertext pages, called cards, without any programming knowledge.

**Hypertext** — an arrangement of the information in a computer database that allows a user to obtain information, and to go from one document to another by clicking on highlighted words or pictures.

**Invariance problem** — used to ‘identify words regardless of how they appear, whether in print or handwritten, in upper- or lowercase, and regardless of their size’. The quick brown fox jumps over the lazy dog chapter 1, figure 5, page 9 graphic show the same characters look different in different fonts and cases and yet they can be identified.

---

**Incunabula** — a book printed before 1501 (that is a book printed the first 50 years of printing with movable type).

**Italics** — type with slopping letter.

**Jurisprudence** — a study of legal theory or legal philosophy.

**Kerning** — in typography, kerning is the process of adjusting the spacing between characters in a proportional font, usually to achieve a visually pleasing result. The historical meaning of kern is somewhat different from the digital sense. The kern is the part of a piece of metal type that overhangs beyond the body (the ‘shank’) so that it can rest on the body of an adjacent character, allowing for tighter spacing and better letter fit. See chapter 2, figure 12, page 50.

**Law of Effect** — responses that produce a satisfying effect in a particular situation become more likely to occur again, while responses that produce a discomforting effect are less likely to be repeated.

**Leading** — the measure from one base line (an imaginary line which the base of capitals rest) of text to the base line of text. This term evolved from the lead, spaces less type height that are used to space out text.

![Leading x-height and base line](image)

**Legibility** — Legibility is the ease with which a reader can recognise individual characters in text. Legibility, is concerned with perceiving letters and words, and with the reading of continuous textual material. Optimal legibility of print, therefore, is achieved by a typographical arrangement in which shapes of letters and other symbols, characteristic word form, and all other typographical factors such as type size, line width, leading etc., are coordinated to produce comfortable vision and ease and rapid reading and comprehension.

---

Letters — ‘letters are individual characters that compose the alphabet, each being primarily a representative form’\textsuperscript{11}. The alphabet is the collection of letters; letters are separate entities and the alphabet is a collective of twenty-six letters of roman type.

Limb — in typography a limb refers to parts of a character i.e. ‘arm’, ‘leg’, ‘cross stroke’ ‘descender’ and ‘ascender’ (see figure 11).

Line length — in typography line length is the width of a block of typeset text, usually measured in units of length like millimeters or points or in characters per line. A block of text or paragraph has a maximum line length that fits a determined design.

Logoi — logoi is the ancient Greek for ‘words’, or ‘things said’.\textsuperscript{12}

Logographic symbols — systems of writing in which each character represents a separate morpheme, also known as ideographic writing systems. The symbols in the system do not show how the word is pronounced, they only represent meaning.


Lower case (lc) — the small letter in a font of typeface.

Luckiesh-Moss Visibility Meter — consists of two photographic filters with precise circular gradients of varying density. These filters can be rotated simultaneously in front of the eyes while performing a visual task, so an object seen through them is just barely discernible.


Manuscripts — A manuscript (abbreviated MS or MSS for plural) is any document written by hand or typewritten, as opposed to being mechanically printed or reproduced in some automated way. More recently it is understood to be an author’s written, typed, or word-processed copy of a work, as distinguished from the print of the same. The noun manuscript evolved from the Latin manu scriptus, meaning “written by hand.” Manu is “hand” and scriptus is “to write.”

Margins — the blank areas on a printed page which surrounds the composed page.

Nelson-Denny Test — The Nelson-Denny Reading Test is a standardised reading test that measures the reading ability of high school and college students. The Nelson-Denny includes two parts: Vocabulary and Comprehension. The first part of the test, Vocabulary, is made up of 80-100 multiple-choice items, each with five response options.

Net or Internet — a global computer network providing a variety of information and communication facilities, consisting of interconnected networks using standardised communication protocols.

Old English Fonts — also known as Black letter, dates back to 1000 years ago when it was used as a script throughout Western Europe. It should be noted that old English or Black letter has nothing to do with the old English language, nor the
old English language written with Black letter. Various forms of black letter exist, for instance, Textualis, the most calligraphic form of the black letter, schwabacher, an old English form that was heavily used in the early German print typefaces, and Fraktur, the most common German black letter typeface.\footnote{Old English fonts. Accesses February 15, 2016. Available: http://fontmeme.com/old-english-fonts/}

\begin{center}
\textbf{Berliner Fraktur}
\end{center}

\begin{center}
\begin{tabular}{c}
AaBbCcDdEeFfGgHhIiJj
KkLlMmUnOoPpQqRrSs
TtUuVvWwXxYyZz
\end{tabular}
\end{center}


\begin{center}
\textbf{Textualis, 14. Jhdt.}
\end{center}

\begin{center}
\begin{tabular}{c}
\texttt{abcdefghijklmnopq\texttt{r}\texttt{s}\texttt{t}\texttt{u}\texttt{v}\texttt{w}\texttt{x}\texttt{y}\texttt{z}}
\texttt{deo p\texttt{z}\texttt{z}. 2 \texttt{s}arend \texttt{qubi3 sagunem}}
\end{tabular}
\end{center}


\begin{center}
\texttt{ABCDEFGHJKLMNPQRSTUVWXYZabcdedfghijklmnopqrstuvwxyz0123456789!?$}
\end{center}

Orbicularis oculi — the muscle encircling the opening of the orbit and functioning to close the eyelids. The word orbicularis comes from the Latin orbis meaning “circle or disk”.

Outcome — related to the amount of information received, and the accuracy of recall and time taken to read the text.

Papyrus — the pith of the papyrus plant is cut into strips, arranged flat, and then pressed into a material for writing.

Parafoveal vision — also called mesopic vision. That part of an image focused on the region of the retina surrounding the fovea. This region contains a mixture of cones and rods and does not provide as high a resolution as does the fovea.14

Paratextual sign — a sign between connecting words to indicate that they are separated words, example a hederæ (hedera leaf, or simply hedera (ivy leaf) symbol).

Aldus leaf fleuron glyphs from a digital font.

Parchment — Goat or sheep skin, scraped and dressed with lime and pumice and used for writing on.

Pareto chart — named after Vilfredo Pareto, is a type of a Pareto chart, also called a Pareto distribution diagram, is a vertical bar graph in which values are plotted in decreasing order of relative frequency from left to right. Pareto charts are extremely useful for analysing what problems need attention first because the taller bars on the chart, which represent frequency, clearly illustrate which variables have the greatest cumulative effect on a given system.

PC — personal computer.

Pecia system — The pecia system (the Latin pecia meaning ‘piece’) was a regulated process of manuscript production used chiefly in the thirteenth, fourteenth, and to some extent fifteenth centuries by the universities.

Philology — the study of the historical development of a language or comparison of different languages.

Phonetic alphabets — a set of symbols used for writing down speech sounds.

Pixels — small separate elements that together form an image on a screen.

Point (pt) — a standard unit of type size. In the British-America system it is 0.01383in, or 72 to the inch or 2.54 cm. The Continental (Didot) point is calculated differently.

Point size — a point size is a relative measure of the size of a font. Distance measured in points is from the highest ascender to the bottom of a descender of a print type. It is used in commercial and computer printing in UK, USA, and other countries, except mainland Europe where type size is expressed in Didot points or as the height of capital (uppercase) letters in millimeters.

Process measures — demonstrates the way the text is read and the way the reader manipulates text.

Proto-Sinaic — also known as Proto-Canaanite, was the first consonantal alphabet.

Putting-out system — a production system in widespread use in 17th-century western Europe by merchant-employers who “put out” materials to rural producers who usually worked in their homes or in workshops.

Pulchritudo adhearens — there are two kinds of beauty: free beauty (pulchritudo vaga), or beauty that is merely dependent (pulchritudo adhaerens). The first presupposes no concept of what the object should be; the second does presuppose such a concept and, with it, an answering perfection of the object.15

Punch-cutting machine — in traditional typography, punchcutting is the craft of cutting letter punches in steel from which matrices were made in copper for type founding in the letterpress.

Ragged left/right — typeset copy where the type is aligned either left or right, example ragged left means the lines are aligned right with uneven line ends on the left.

RAR — or resolution/addressability ratios, ‘the ratio of resolution to addressability (RAR) can be calculated by taking into account the pixel pitch, p (display height divided by the number of addressed lines), and the spot size, s: RAR=s/p, there are several factors that affect the resolution in CRT displays. One of these factors is the spot size, which depends on the phosphor layer but also on the electron beam current and the optics of the display system.’16

Readability — The readability has to do with how easy, difficult, interesting, or accessible its contents are, relative to the reader.17

**Retina Display** — is a marketing term developed by Apple to refer to devices and monitors that have a resolution and pixel density so high — roughly 300 or more pixels per inch — that a person is unable to discern the individual pixels at a normal viewing distance.

**Retinotopic organisation** — retinotopic organisation is the design feature in our visual system where soon after birth each neuron in the eye’s retina begins to correspond to a specific set of cells in the occipital lobes.

**Right type** — the right type is a traditional assumption of what font is right for a certain job though it is not something that can be defined.

**Roman type** — the normal typography style in which the vertical lines of the characters are straight up and not at an angle. It is the opposite of italic that uses slanted lines. The first roman type was based on a formal book hand that was perfected in Italy by humanistic scribes during the first half of the fifteenth century. It was first used chiefly for editions by classical authors. Today, when we say roman type we refer to the characters or symbols, i.e. the twenty-six characters found in the English alphabet. Roman type’ consists of the roman alphabet, uppercase, lowercase and small caps: The normal roman type (in simple form without special sort, etc.) consists of an upright design, and a sloping form of it:

\[
\begin{align*}
\text{ABCDEFGHIJKLMNOPQRSTUVWXYZ} & \quad \text{abcdefghijklmnopqrstuvwxyz} \\
\text{ABCDEFGHIJKLMNOPQRSTUVWXYZ} & \quad \text{abcdefghijklmnopqrstuvwxyz}\text{18}
\end{align*}
\]

**Roman alphabet** — the alphabet evolved by the ancient Romans for the writing of Latin, based upon an Etruscan form derived from the Greeks and originally from the Phoenicians. The alphabet serves for writing most of the languages of Western Europe and many other languages. ‘The alphabet is a system and series of symbols representing collectively the elements of written language’\(^{19}\). The alphabet is the collection of letters (also referred to as the Latin alphabet).

**Saccade** — a small rapid jerky movement of the eye, jumping from one fixation point to another, reading takes place in the fixation point not in the saccade. Saccade is a French word, meaning jerk or twitch. See chapter 3, figure 30, page 105.

**Sans serif** — a typeface without serifs (decorative flourishes) and usually without stroke contract.

**Serif** — a typeface with serifs (serifs are the small terminal stroke stemming from, and at an angle to the upper and lower ends of the stroke of a letter)

**Script** — printed letters resembling handwriting.

---


\(^{19}\) Frederic W. Goudy, *Typologia* (Berkeley, California, USA, University of California Press, 1977), 124.
**Scriptura continua** — books with no word spacing are now referred to as *scriptura continua*, i.e. words that ran together without any breaks across the lines on every page. See chapter 1, figure 6, page 10.

**Scrolls** — a roll made out of paper, parchment, papyrus, vellum or other material used for a written document.

**Short-exposure method** — a method used for the measuring of the relative legibility of letters and digits, specific letters in different typefaces and the effect of variations in brightness contract between paper and print. It measured legibility by determining the speed and the accurate perception of printed symbols. The apparatus that was used for short-exposure was termed a tachistoscope.

**Signifier, signified and sign** — a spoken word with an aspect we can hear (picture in our minds eye) and a written word is an aspect we can see, this is what Saussure called a ‘signified’ and ‘signifier’. A ‘signified’ is a concept or meaning associated with that sensory perception.

**Spacing** — the spacing between characters of text for selected text or for particular characters. In addition, you can stretch or compress an entire paragraph to make it fit and look the way that you want it to.

**Speed of reading method** — a method used more for checking the comprehension of text and not the legibility of text. One such speed of reading test was designed in 1923 by Chapman and Cook, this test has been proven to produce a pure test of speed of reading performance uncomplicated by a comprehension factor. The difference in typefaces used in the items was a single variable. The test contained 30 items of 30 words in each. The vocabulary used was relatively simple. Each item contained one word to spoil the meaning. This word had to be crossed out by the reader.

**Sumerian writing** — a system of writing derived the language of the Sumerians that has no known relationship with any other language. Sumerian writing originally contained about nine hundred signs and over time was reduced to five hundred signs as syllabic writing increased. The Sumerians formed one of the earliest urban societies, in Southern Mesopotamia more than 5000 years ago. They developed a writing system whose wedge-shaped strokes would influence the style of scripts in the same geographical area for the next 3000 years. Eventually, all of these diverse writing systems, which encompass both logo-phonetic, consonantal alphabetic, and syllabic systems, became known as cuneiform.

---

Swash letters — a typographical letter having strokes ending in an extended flourish or old style face italic type with calligraphic flourishes.

Tablet or clay tablet — a flat slab or plaque suitable for inscribing or bearing an inscription.

Tachistoscope — an apparatus used to investigate the legibility of typography.

Tachistoscopic method — a method involving a pre-exposure field, and an exposure field, switching between each at a controlled time interval. The exposure field contains the printed material and a post-exposure field. In some tachistoscopes the post-exposure field and the pre-exposure field are the same. The exposed field is viewed briefly at about 1/10 second or less and this is enough time for a clear view of the print, and also this period of time means that the exposure to the print is shorter than the reaction time of the eye. ‘This arrangement yields a single act of vision, since the timing prevents movement of the eye to a second fixation point.’ When this method is used to measure the speed of vision the exposure to the print is reduced to accurately identify the symbol.

Type — a font is a set of printable or displayable text character in a specific style and size. The type design for a set of fonts is the typeface and variations of this design form the typeface family. Thus, Helvetica is a typeface family, Helvetica italic is a typeface, and Helvetica italic 10-point is a font.

Typeface — a set of letters, numbers, etc., that are all in the same style and that are used in printing—usage, synonyms, more.

Type family — a term covering all the variations and sizes of a basic typeface design i.e. roman, bold, italic, bold italic, black, black italic, condensed, bold condensed, black condensed…

Upper case (Uc) — the capital letter in a font of typeface.

VDU — a VDU is a Visual Display Unit. It is another term for monitor or screen, but may also refer to a projector or other type of display.

Vellum — the treated skin of a calf, kid or lamb used as a writing surface — a fine-grained unsplit lambskin, kidskin or calfskin prepared especially for writing on or binding books.

Vernacular books — books written in a language or dialect native to a region or country rather than in a literary, learned, or foreign language.

Web — (world wide web or www) an information system on the Internet which allows documents to be connected to other documents by hypertext links, enabling the user to search for information by moving from one document to another.

Word — a single distinct meaningful element of speech or writing, used with others (or sometimes alone) to form a sentence and typically shown with a space on either side when written or printed.

x-height — the height of the lower case character with no ascenders and no descenders called after the lower case ‘x’ which has no ascenders or descenders.
Appendix One

Research into Legibility and Readability

Appendix contains a list of experiments/research carried out into legibility and readability grouped by researcher and author and the year when the research was undertaken.

Research into legibility and readability was notably comprehensive, for example, Pyke in 1926 identified 251 studies and papers between 1825 and 1926:

- **Contrast in thickness and thinness** (i.e. as opposed to uniform thickness of limbs)
  - 10 writers in 100 years: 1825-1924
- **Criterion of legibility** — 36 writers in 98 years: 1827-1924
- **Definition of legibility** — 9 writers in 44 years: 1878-1921
- **Faces of type** — 28 writers in 101 years: 1825-1925 [sic]
- **Illumination** — 13 writers in 46 years: 1879-1924 [sic]
- **Indentation** — 4 writers in 13 years: 1905-1917
- **Leading** — 20 writers in 46 years: 1880-1925
- **‘Legibility’ of letters** — 12 writers in 41 years: 1885-1925
- **Length of lines** — 13 writers in 43 years: 1881-1923
- **Margins** — 9 writers in 42 years: 1881-1923
- **Paper and ink** — 20 writers in 99 years: 1827-1925
- **‘Projectors’ or long sorts** (i.e. characters which project above or below the line or do both) — 4 writers in 98 years: 1827-1924
- **Serifs** — 12 writers in 98 years: 1825-1922
- **Size of type** — 18 writers in 98 years: 1827-1924
- **Spacing** — 18 writers in 44 years: 1881-1924
- **Thickness of limbs** — 12 writers in 33 years: 1878-1921
- **‘The Ideal Type’** — 13 writers in 47 years: 1788-1924 [sic]

Legibility Studies

1790: Jean Anisson in an experiment showed that a page set in Garamond could be read from a point further away than a page set in Didot type of the same size. The reason for the experiment was that Anisson ‘disliked the new Didot design’ and

---

‘was apparently motivated by a desire to prove that Garamond type was more legible.’

1825: Hansard, T. wrote a paper on the contrast in thickness and thinness of lines and declared that he was ‘opposed to extreme contrast.’ He was also opposed to the elements found in type: (i) extreme kinds of faces design, (ii) excessively fine hair-lines, (iii) excessively fine serifs, (iv) extreme thick-and-thinness, (v) uniform thickness (‘Egyptian Antique’). He stated: ‘Clearness or facility of reading depends not only on size of type, but on the ratio of size of type to interlinear space.’

1827: Baddage, C. saw ‘majority of “votes” as to “facility in reading” with different shades of paper,’ as criteria of legibility. He inspected a number of books of mathematical tables for the width of leading. Resulting: uniformity is better than variation in height because the figures then interfere less with the space between the lines. Where size of type was taken into account he concluded: ‘Clearness or facility of reading depends not only on size of type, but on the ratio of size of type to interlinear space.’

1865: Cohn wrote the first systematic study of myopia in schools: 10,060 children were studied. (Javal referred to this research in a paper on writing.)

1878: Rahlmann used mechanical means to measure nystagmus (i.e. rapid involuntary oscillation of the eyeball) in his research.

1878-1881 and 1905: Louis-Émile Javal was the first to undertake a scientific study of reading and eye-movement. He wrote a series of papers on the visual processes involved in reading that covered the following topics: (i) Size of letters; (ii) Fatigue on accommodation muscles; (iii) Distance from normal eye at which pages of print can be read; (iv) Distance from myopic eye at which pages of print can be just recognised; (v) ‘Confusability’; (vi) Simplicity of letter form; and (vii) Degree of illumination necessary for a given reading performance. Using the definition of legibility of both a typeface and individual letters to be read far off and read in dim light.

---

2 G. Thomas Tanselle, Bibliographical Analysis, A Historical Introduction (United Kingdom: Cambridge University Press, 2009), 110.
4 Ibid., 101.
5 Ibid., p98.
6 Ibid., p101.
1879: Diseases of the eye and the use of glasses, September 27 of the same year.

1879: Public and private lighting, from the point of view of the hygiene of the eyes, October 18 of the same year.

1879: Books and myopia, November 22 of the same year.

1881: Mechanism of writing, May 21 of the same year.\(^9\)

Between 1878-81 and 1905 Javal looked at serifs in relation to (i) irradiation and (ii) distance at which letters can be read. Concluding (i) in favour of serifs; (ii) they should be thickish, short, triangular, not as in French 1750-1900, long, thin, and rectangular. If the latter, they meet, e.g., in n, and cause confusion with, e.g., u.; (iii) long, thin serifs break easily; and (iv) rounded are best. Elzevir better than English.\(^10\) Javal’s study into the ideal typography outlined his view on each character for example: ‘n. as it is.’, ‘t. cross-bar well to the left, short and thick. Horizontal lower serif at foot is best; but at least minimize hook, because it is inevitably thin, which is bad.’\(^11\)

1879: Hering measured eye movements to describe discontinuous eye movement during reading.

1879, 1892: M. Lamare carried out experiments in Javal’s laboratory and demonstrated that the horizontal movement of the eyes during reading was not continuous, which Javal called \textit{saccades}. In 1892 he used the method: ‘number of letters that can be grasped by the eye in one reading pause.’\(^12\) Lamare counted the number of eye movements by placing his finger on (own) lid and used an eye-attachment which made taps on a drum. As a result of these experiments he favoured condensed faces of good-sized gauge.

1880: Javal, E. studied leading, impression by scanning pages set up leaded and solid.

He stated that increasing legibility is a practical problem, as paper costs sometime and therefore leading and spacing often cannot be afforded. ‘[He seems to imply here that, economics apart, there might be something in favour of leading.]

Javal also looked at the thickness of limbs in 1880 and 1885 and concluded:

---


\(^11\) \textit{Ibid.}, p107.

\(^12\) \textit{Ibid.}, p65.

\(^13\) \textit{Ibid.}, p81.
Must be greater than if letters were designed solely for the perfect eye, so as to suit all conditions. Limit is when letter begins to lose its shape.\textsuperscript{14}

1881: Weber, A. studied the length of lines and his results by using the minimum line length 100mm and a maximum line length 150mm that the optimum line length was 125mm. Criterion (i) Speed of reading (i.e. number of letters read per minute); (ii) Degree of strain on a child’s growing eye.\textsuperscript{15} Weber’s used the definition of legibility of a typeface as the ability to be read quickly and easily. Weber also investigation in schools leading and strain on a child’s growing eye and stressed the importance of the ratio of interlineage (leading) to gauge 2 : 1.5 for Fraktur and 2 : 1.75 for Antiqua.\textsuperscript{16} In relation to the size of type experimental basis: 6 (educated) subjects, (a) Silent, (b) (as a control) loud reading for 1 min. Investigation in schools by speed of reading and strain on child’s growing eye. He concluded: (i) minimum gauge 1.5 mm. Maximum 2 mm. (ii) A gauge of more than 1.9 mm, does not increase speed of reading, and one of over 2mm. hinders. (iii) The ratio of gauge to interlineage is important. It should be 1.5 : 2 for Fraktur, and 1.75 : 2 for Antiqua.\textsuperscript{17} Weber study with spacing and speed of reading found that the optimum (and maximum) numbers of letters per line of 100.3mm : 60. Maximum number of letters per line of 100.3mm : 50.\textsuperscript{18}

1883: Cohn, H. studied the length of lines with the ‘fatigue on eye’ method and his results showed that characters of a gauge of 1.5mm were the minimum line length 90mm and a maximum line length 100mm and 110mm that the optimum line length was 95mm. He used criterion: ‘The degree of myopia produced by reading.’\textsuperscript{19} Cohn’s definition of letters was essentially the ability to read easily, ‘that is, fluently, for a good length of time and comfortably at a distance of 20 in, or \( \frac{1}{2} \) m.’\textsuperscript{20} Also indicated that ‘a smaller type leaded is, or can be, more legible than a larger type solid.’\textsuperscript{21} He also looked at ocular fatigue and concluded: ‘Is in favour of retention, and of their being of good length because their “breaking of the monotony of the short letters is very beneficial to the eye as it prevents fatigue”’.\textsuperscript{22} Cohn study into thickness of limbs and eye strain in children found:

\begin{itemize}
  \item \textsuperscript{14, 16} R. L. Pyke, \textit{The Legibility of Print} (Special Report Series, No. 110. Medical Research Council. London: His Majesty’s Stationery Office, 1926), 111.
  \item \textsuperscript{15} Ibid., p65.
  \item \textsuperscript{16} Ibid., p81.
  \item \textsuperscript{17} Ibid., p101.
  \item \textsuperscript{18} Ibid., p104.
  \item \textsuperscript{19} Ibid., p65.
  \item \textsuperscript{20} Ibid., p68.
  \item \textsuperscript{21} Ibid., p81.
  \item \textsuperscript{22} Ibid., p98.
\end{itemize}
Minimum fro main stroke 0.25 mm. in school books. Physiologically, thick strokes are best, as ‘the picture on the retina is broader and therefore can be read more easily’.

1884: Schneller looked at size of type and legibility and concluded: ‘The minimum width of main-strokes should be 0.3mm.; of counter of n, 0.3mm.’

1885: Cattell, James McKeen showed in several experiments that the eye could grasp the whole word as quickly as a letter, and that sense material or sense words were read at a greater speed than nonsense material. He also looked at the use of punctuation and legibility and concluded: ‘Absolutely useless. Would substitute by different sized spaces.’

1885: Cattell used a Tachistoscopic reading with his fall-chronometer. He found that the speed of reading isolated letters in relation to the thickness and thinness of limbs; proportion of correct answers to total numbers of exposure resulted in a ‘double utility of using thick lines and thin lines’. The criterion used by him: ‘Time taken to recognize 50 per cent of words or letters when exposed for small fractions of a second.’

188(5 ?): Flick, A. studied faces of type with the judgement of favours square-shaped letters. Flick also looked at leading and the ease in changing from line to line and concluded that leading should vary according to length of line and the optimum proportion of length of line to interlineage is 40:1. Flick view on size of type was as follows: ‘The ratio of width of main-stroke to gauge of lower-case letters should be as 1 : 5.’ Flick study of thickness of limbs found: ‘The ratio of width of main stroke to gauge of lower case should be as 1 : 5.’

188(5?): Stettler studied the size of type for legibility and thickness of limbs and in both studies concluded the same as Flick 188(5?).

1888: Sanford, E. C. published his findings in ‘The Relative Legibility of the Small Letters’ using criteria of (i) the distance at which (isolated) letters can be read (aloud) and (ii) ‘The number of times a(n isolated) letter was read right or wrong,

---

24 Ibid., p101.
29 Ibid., p69.
30 Ibid., p81.
31 Ibid., p101.
32 Ibid., p111.
when seen for a very small fraction of a second.’ Concluding letters should possess ‘simplicity of outline, concentration of the differentiations upon one particular’. Breadth is generally a greater advantage than height and broad short letters are better than long narrow ones.\textsuperscript{33}

1891: Ahrens applied a mechanical means similar to Rählmann’s 1878 method to reading. Ahrens was not able to obtain any detailed recordings of eye movements.

1891: Landolt observed eye movement directly in the context of reading.

1892: Lamare worked on the number of letters that can be grasped by the eye in one reading pause. For lowercase he favours condensed faces of good-size gauge.\textsuperscript{34} He also studied the size of type and concluded that (i) a tall letter is better than a shorter one and (ii) he advises a large narrow letter.\textsuperscript{35}

1893: Goldscheider & Müller worked on the belief that the easy recognition of words depended on dominant letter they experimented with leaving out letters in words e.g. D-a-nose (diagnose). The dominants were regarded as auditory-motor as well as visual stimuli.

1896: Griffing, H. and Franz, S. I.: The first experimental study ever published that dealt with the legibility of sans serif typefaces compared to serif typefaces. This was initially presented to the International Congress of Psychology in Munich in 1896 and published in the American journal \textit{Psychological Review}.\textsuperscript{36} The criteria were fatigue through illumination threshold based on (i) Time taken to read a given amount in different types (silently); (ii) Number of words read (at maximum speed); (iii) Percentage of words read to total exposed (in a fall-screen); and (iv) Intensity of illumination required for a given reading performance. The resulting judgment was ‘Thin hair-lines if with thick lines do not seem to diminish legibility.’\textsuperscript{37} Griffing and Franz also studied leading and fatigue by illumination thresholds. Griffing and Franz in the same year looked at paper colour and legibility and outlined in descending order of legibility (i) white, (ii) greyish, (iii) yellow and (iv) red. Their theory is that hue as such is immaterial provided the colour of the paper absorbs a minimum light, and the


\textsuperscript{34} R. L. Pyke, \textit{The Legibility of Print} (Special Report Series, No. 110. Medical Research Council. London: His Majesty’s Stationery Office, 1926), 69.

\textsuperscript{35} Ibid., p102.

\textsuperscript{36} Ole Lund, ‘Knowledge Construction in Typography’. The case of legibility research and the legibility of sans serif typefaces. Thesis (PhD), 1999. The University of Reading, Department of Typography and Graphic Communication, 92.

order here is their intensity-order when the surface is matt. Size of type was also looked at and they concluded that the most important factor is size of type (i) 1.5 mm. should be the minimum gauge and (ii) Fatigue coefficient increases slowly from a gauge of 6 mm. down to one of 1.6 mm. and increases quickly below that. Griffing and Franz looked at spacing on two kinds of Roman, one German and one Black uppercase type on three subjects with twelve experiments with a Petrol hooded lamp of 0.02 candle-power and 1-4 words exposed at a time. ‘They imply that a increase in spacing would be an improvement (though their own experiments results are negative), but that the economics of printing probably makes it inadvisable.’

A study into the thickness of limbs was also carried in 1896 by Griffing and Franz and concluded: ‘Increased thickness of limbs even when not throughout all the lines of a letter, increased the legibility of the faces tested.’

1896: Morris W. studied the contrast in thickness and thinness of limbs from an aesthetic point of view and gave a judgment of ‘entirely opposed to any degree’.

1896: Sack, N. investigated leading in school and found that the interlinage should not be less than 2.5mm. In his study on the thickness of limbs he found: ‘The thickness of the vertical stroke of the lower-case letters should be 0.3 mm.’

In his study of spacing he concluded:

(i) The space within the letters between the vertical strokes should not be less than 0.5mm. (ii) The space between the letters of a word should not be less than 0.5 to 0.75mm. (iii) The space between the words should not be less than 2mm. (iv) The number of letters per running centimeter should not be more than 6 to 7.

1897: Pillsbury conducted experiments with misspelling words presented by tachistoscope and substantiated the Erdmann–Dodge theory of word-wholeness. Pillsbury found that disfigurements in the beginning of a word are much more easily recognised that in the end of a word.

1898: Morris, W. studies typefaces coming to the conclusion: ‘“The ugly and vulgar illegibility of the modern faces, and the elegance and legibility of the old styles” are particularly striking in the numbers.’

Morris also looked at paper based on

---

39 Ibid., p102.
40 Ibid., p104.
41 Ibid., p112.
42 Ibid., p64.
43 Ibid., p81.
44 Ibid., p112.
46 Ibid., p70.
aesthetic and economic criteria and indicated that paper should be (i) hard, (ii) little ribbed, (iii) durable, (iv) unglazed and (v) handmade.\textsuperscript{47} Morris’s study with spacing based on aesthetics resulted in the following: ‘There should be minimum and equal spaces between words (i.e. no “rivers”).’\textsuperscript{48} Morris found in his study of thickness of limbs that ‘the limbs should be “rather” thick.’\textsuperscript{49}

1898: Delabarre recorded eye movement during reading.

1898, 1900: Huey recorded eye movement during reading.

1898: Erdmann and Dodge observed reader’s eyes through a mirror and found that (i) words could be perceived by indirect vision where single letters could not, (ii) that words with a characteristic form were read at a distance more easily than words of a more even appearance, and finally, (iii) that the same applied for direct vision to words could be perceived where single letters could not if changes were made to the size of the words and characters and also by changing the distance. They also demonstrated that actual reading takes place during the fixation-pause and that the eye sees little or nothing while moving\textsuperscript{50}.

1900: De Vinne, T. L.: his criterion for legibility was ‘distance of book from eye at which remains “distinct”’ Concluding: Old Style is superior in distance to Modern faces, sharp lines and dazzling serifs make all the light faces hard to read and for bodies below 10-point a narrowing that makes their lower-case alphabets thinner than that of the prevailing standard is not to be recommended.\textsuperscript{51} He also studied serifs and concluded ‘sharp lines and dazzling serifs make all the light faces hard to read.’\textsuperscript{52}

1901: J. Finzi, investigation of the faculties of perception and retention in memory using the method of brief exposure from the percentage of misreading of each letter he computed the order of legibility as follows: P U A Q X T D S E W M V Y Z H C N F L R G B K O I.

1902: Burgerstein, l. and Netolitzky, A. investigated typefaces in schools. They prefer Antiqua ro Fraktur, particularly for uppercase.\textsuperscript{53} Where spacing was looked at they concluded (point (iii) agrees with Sack, N. (1896) finding on the number of letter per running centimeter at not more than 6 or 7.):

\textsuperscript{48} Ibid., p105.
\textsuperscript{49} Ibid., p112.
\textsuperscript{52} Ibid., p100.
\textsuperscript{53} Ibid., p70.
(i) ‘The space between the letters of a word should be greater than the distance between two neighbouring ground strokes of a letter.’
(ii) The space between the words should not be less than 2mm.
(iii) The number of letters per running centimeter should not be more than 6 or 7.\textsuperscript{54}

1903: Cohn, H. and Rübencamp, R. comprehensive study is one of the earliest that dealt with problems of perception and sensation under a number of typographical conditions. The study made recommendations as to type size, line width, leading and colour.\textsuperscript{55}

1903: Cohn, H. and Rübencamp, R. studied typefaces with the ability to be read at a distance of 20in. and the influence upon myopia resulting: prefer Antiqua to Franktur.\textsuperscript{56}

1904: Pergens, E. definition of legibility of individual letters, i.e. the ability to read far off. He also studied serifs by addition and removal bit by bit of the serifs in upper case letters and then counting the number of correct recognitions by the ‘distance method’ and isolated letters. He concluded: (i) serifs increase legibility in some cases but diminish it in most and (ii) in any case they help only if on the ‘external’ part of letters.\textsuperscript{57} In his study on type size by distance from the eye that isolated letters can be read he concluded:

Increasing gauge increases legibility of (i) those letters formed solely of straight lines, not containing right angles, viz. V, M, W, Y, X, N, Z, K, A; and (ii) up to a point those letters formed solely of straight lines containing only right angles, viz. I, L, E, F, T, H.\textsuperscript{58}

1904: Messmer, O. studied the difference in reading Roman type and German Gothic (Fraktur). The method used was ordinary reading without tachistoscope recording the time taken for 100 and 500 words and 100 and 500 letters, and resulting in Roman type which on the whole reads more quickly than German Gothic.\textsuperscript{59}

1905: Javal, E. studied the contrast in thickness and thinness of lines and his conclusion is in favour of some contrast: for if limbs of uniformly thick optimum thickness depends on illumination. Illumination can come in different levels from bad to good but the limit of the thickness of limbs as with limbs of more than a given thickness a letter of a given size will lose its shape. ‘This danger-point is however, reached less soon if we thicken some limbs, or part of lines, only. Hence

\textsuperscript{56} R. L. Pyke, \textit{The Legibility of Print} (Special Report Series, No. 110. Medical Research Council. London: His Majesty’s Stationery Office, 1926), 70.
\textsuperscript{57} \textit{Ibid.}, p100.
\textsuperscript{58} \textit{Ibid.}, p102.
\textsuperscript{59} \textit{Ibid.}, p70.
contrast. In his study on the size of type using the distance method and reading a printed page, he concluded for lower-case characters:

(i) Size of type is the most important factor in legibility.
(ii) 5-point should be used only when the counters are at least equal in width to the main-stokes.
(iii) 10-point optimum for presbyopes.
(iv) 8-point optimum for myopes.
(v) 9-point is sufficiently big in general.  

1905: Slefrig, S. studied indentation and his research found that the lines should be indented on the right and there should be no hyphenation. He also looked at the colour of paper and ink and stated that white letters on a dark page would be in many ways more legible than the converse. A third topic he looked at was serifs by irradiation and concluded: 'serifs should be triangular, not linear.'

1906: Dearborn studied the length of lines and concluded that the optimum line length was 80mm. The criteria used were (i) Speed of reading; (ii) Number of eye pauses; (iii) Number of refixations; and (iv) Degree of regularity of eye movement. Dearborn analysis of eye movement was by means of photography with a pencil of light reflected from the cornea during silent reading. Dearborn also looked at leading and found that an increase of spacing between the lines increases legibility as much as a larger size of type. '[His results on leading were a side issue incidental to work on length of line.]

1906: Hamilton, F. M. studied legibility by using the following criterion: number of correct recognitions of letters in short exposure taking account of the different position they occupied in a word.

1907: Ruediger, W. C. studied the length of lines with the ‘speed method’ with a tachistoscopic and found that the optimum line length was 80mm for characters of a gauge of 1.5mm. The criteria used were the amount that can be grasped in a single fixation; and the amount read (silently) at normal and at maximum speed.

---

61 Ibid., p102.
62 Ibid., p95.
63 Ibid., p100.
64 Ibid., p65.
65 Ibid., p82.
66 Ibid., p92-93.
67 Ibid., p66.
68 Ibid., p66.
1907: Scott W. D. studied the time taken to read pages of a railway time-table in two typefaces and also the errors in reading same.\textsuperscript{69}

1908: Kirschmann, A. studied legibility by using the criterion of the distance (along various meridians) peripherally from a fixation point at which isolated letters could be read.\textsuperscript{70} His definition of legibility of individual letters was the ability to be recognised peripherally.

1908: Maire, A. studied the length of lines with a maximum line length of 100mm. The method used was that of the distance from the eye at which a row of letters can be read. Maire distinguished legibility from visibility. Visibility refers to the mark made upon the paper by a letter and is measured by the distance from the eye at which the letter alone ceases to be distinguishable from the paper or if among other letters becomes merged with them. Legibility ‘consists in it being possible to define clearly with the eye the design of the letter, that is its contours, and therefore the ensemble of the letters of a single word.’ For Maire legibility stands in direct relation to (i) letter-shape, (ii) ratio of letter-height to letter-width, (iii) thickness of main-stroke and hair-lines, and (iv) the internal and surrounding white space.\textsuperscript{71} Maire also looked at leading and intellectual fatigue and found that for works on mathematics, chemistry, physics, medicine and natural sciences that with a 9pt with a leading of 10.5pt to 11.5 pt is better than set solid.\textsuperscript{72}

1908: Wiegand, C. F. studied legibility by using the criterion of distance at which an approaching word becomes recognisable.\textsuperscript{73}

1910: Dockeray, F. C. studied the distance peripherally from fixation point at which two isolated letters could be recognised, one letter on each side. Finding broad letters are the most legible; narrow letters and some tall ones are the least.\textsuperscript{74}

1910: Huey, E. B. studied the length of lines with the fatigue and speed method giving the optimum line length of 60mm. The criteria used were as follows: (i) speed of reading; (ii) fatigue on accommodation muscles; (iii) number of words per fixation; and (iv) light-reflecting power of paper.\textsuperscript{75} Huey also looked at leading and concluded that ‘leading is doubtless a mistake when the size of type is less than 1.5mm for lowercase non-projectors’\textsuperscript{76} Huey also looked at legibility and the


\textsuperscript{70} Ibid., p66.

\textsuperscript{71} Ibid., p68.

\textsuperscript{72} Ibid., p82.

\textsuperscript{73} Ibid., p66.

\textsuperscript{74} Ibid., p66.

\textsuperscript{75} Ibid., p66.

\textsuperscript{76} Ibid., p82.
degree of contrast with paper and type and concluded that (i) the paper should be pure white and without gloss, (ii) paper of a slightly yellowish tinge is probably not injurious, but pure white gives the greatest legibility and (iii) The print of one side must not show through to the other, and the printing must be so done that it will not affect the evenness of surface of the other side. 77 In the study of size of type by speed of reading and fatigue, he concluded:

(i) The size of type is perhaps the most important single factor in legibility. (ii) Preferably the height of the lower-caes non-projector should be somewhat above the minimum of 1.5 mm. on which investigators are generally agreed, but not much above 2mm. 78

In Huey study on spacing and speed of reading he concluded:

(i) There is probably little to be gained by increasing the distance between the letters (of a word) beyond that which is usually in the better printed books of the present time. (ii) When the same number of words was printed in fewer lines of the same length and the same size of type, they were read faster in just the proportion that the lines were fewer. 79

1911: American School Hygiene Association looked at legibility and paper, found that for adults the paper should be unglazed and free from shine and opaque. In the study of spacing for adults they found: ‘(i) Spacing between letters: 0.5–0.75 mm. (ii) Minimum space between words: 2 mm.’ 80

1912 and 1915: British Association studied the length of lines with the fatigue on eye method with a maximum line length of 93mm. This study was directed at the influence of school-books on eyesight and was based on statistical inquiry into strain on (child’s) growing eye. The result was: ‘excessive contrast bad. “Slight” thickening of limbs does not matter.’ 81 The criteria used were (i) strain on growing eye; (ii) strain on accommodation muscles; (iii) speed and accuracy of changing line; (iv) effect on reading rhythm; and (v) height and breadth of short letters. 82 When they included paper and ink in their study, they concluded that (i) cream is the best colour for average of all uses though white actually gives the best contrast, (ii) the paper should have no glaze, (iii) it should be hard pressed to avoid easy soiling or rubbed surface, (iv) it should be thick to prevent print on

78 Ibid., p103.
79 Ibid., p105.
80 Ibid., p105.
81 Ibid., p64.
back showing through and (v) glare is likely to be injurious when specular reflection exceeds 26% and diffuse reflection is less than 44%. The risk is greater still in artificial light.\(^3\)

1912: Barbara Elisabeth Roethlein’s research involved the relative legibility of different faces of printing types and she used a technique limited to the specific situation of legibility of isolated characters and groups of characters. She used the distance from the eye that single letters could be correctly recognised. Roethlein’s conclusions were as follows.

1. Certain faces of type are much more legible than other faces; and certain letters of every face are much more legible than other letters of the same face.
2. These differences in legibility prove to be greater when letters are presented in isolation from one another than when they are presented in groups.
3. Legibility is a product of six factors: [1] the form of the letter; [2] the size of the letter; [3] the heaviness of the face of the letter [the thickness of the line which constitute the letter]; [4] the width of the white margins which surrounds the letter; [5] the position of the letter in the letter-group; [6] the shape and size of the adjacent letter. In our experiments the first factor seemed to be less significant than any of the other five; ie in the type-faces which were employed in the present investigation the form of any given letter of the alphabet usually varied between such narrow limits as to constitute a relatively insignificant factor in the determination of its legibility.
4. The relatively heavy-face types prove to be more legible than the light-faced types. The optimal heaviness of faces seems to be in a mean between the bold faces and such light faces as Scotch Roman and Cushing Monotone.
5. The initial position in a group of letters is the most advantageous position for legibility; the final position comes next in order of advantage; and the intermediate or internal position are least favourable for legibility.
6. The size and the form of the letters which stand adjacent to any given letter play an important role in determining its legibility and the misreading which occur in the case of grouped letters are of a wholly different sort from those which occur in the case of isolated letters. When letters of the same height or of similar form appear side by side, they become relatively illegible. But the juxtaposition of an ascender, a descender and a short letter tends to improve the legibility of each, as also does the juxtaposition of letters which are made up wholly or chiefly of straight lines and letters which are made up wholly or chiefly of curved lines.
7. The quality and the texture of the paper is a much less significant factor than has been supposed, — provided of course, that the illumination and the inclination of the paper are such as to secure an optimal condition of light reflection from its surface.

8. There is an urgent need for modification of certain letters of the alphabet.  

1912: Jacobi, C. T. studied margins with double page is the unit. Finding that the inside margin should be narrowest. Top margin should be next in width. Outer margin should be next in width and the bottom margin should be the widest.  

1914: Parsons, J. H. studied illumination and concluded that minimum illumination of the type which permits normal visual acuity with Snellen’s test is 2–3 meter-candles with vision improving as illumination was increased to 10 meter-candles after which it remained almost constant up to 30 meter-candles and over. He also looked at serifs and concluded: ‘Favours them a priori. Visibility improved if they are triangular.’ From his study on spacing he concluded:

(i) Round letters (e.g. two ‘O’s) when adjacent should actually have less space on either side of them than straight letters.
(ii) Inter-letter space should not be less than that between the main strokes of the n.  

1916: Freeman, F. N. studied the length of line with the speed of reading method. Findings that lines of 11pt type 24 ems in length were read slightly faster than those of 12 ems and there are more reading pauses (though of shorter duration) in the line of 12 than 24 ems and this involved a certain wastage of eye movements, since a certain number are solely due to the frequently recurring end of line required a part of a fresh movement and preventing the reader’s true rhythm. Freeman also looked at type size by counting eye pauses by observation of subject’s eye in a mirror, with 14 subjects and speed of reading (silently) (i) at normal and (ii) at maximum speed by time taken to read a given passage. He concluded firstly that 7pt type was read most rapidly: (i) on the average and (ii) by 8 out of 14 subjects, than 11-point. His second conclusion was: ‘The finer type seems to allow somewhat greater scope of fixation, but the number of fixations per second does not increase.’  

1916: Legros and Grant studied legibility coefficient and specific legibility. The criterion used was as follows: For a given pair of letters (e.g. a and s, e and c, i and l, etc.) calculated the ratio of ‘the sum of the area peculiar to the individual character to the sum of the total areas of the two characters and this they called the

---

86 Ibid., p78. 
87 Ibid., p101. 
88 Ibid., p106. 
89 Ibid., p92. 
90 Ibid., p103.
legibility coefficient. The 100% was considered perfect legibility or that there was no coefficient and going on this principle the difference between 100% and the legibility coefficient was termed the ‘illegibility coefficient’. To obtain an accurate idea of the influence of each character on the legibility as a whole the illegibility coefficient is multiplied by the recurrence of the character as given in the typeface bill and the product termed the ‘illegibility factor’ the sun of these legibility factors derived by the total recurrence of the character under consideration gives the mean ‘illegibility factor’. Using this method different styles of faces can be compared providing other conditions such as dimensions in guage, main-stroke, hair-line and set-width are sensibly constructed. The resulting uniformity of the face can be measured by the ratio of the total area of the face of the character to the cross section of the type, this figure given as a percentage has been termed ‘blackness’. Legros and Grant found that it was obvious with increasing blackness, other conditions remaining constant, the coincident area are increased and the legibility coefficient decreases, and vice versa.

If there was no coincidence to consider, the actual legibility may be assumed to vary directly as the blackness; hence the best comparative figure will be obtained as the obtained as the product of the mean legibility coefficient by the mean blackness.\(^9\)

This is what Legros and Grant called the ‘specific legibility’. Legros and Grant also looked at punctuation and they criticize Cattell’s 1885 remark on punctuation ‘absolutely useless’ and gave the opinion:

…this proposal has many merits, but it is subject to one grave disadvantage. The spacing of the different lines of printed matter must necessarily vary in order to keep the length constant, and nay such system would require that the space to denote the pause for a comma should, at least, be equal to a noticeable increase on the widest ordinary spacing, and a substantially larger maximum would be required to correspond to the long pause given for the period.\(^9\)

Legros and Grant also looked at spacing for children’s school books and found:

‘(i) The a-z length should not be less than 13 ems. (ii) The normal space between words should not be less than the en quad.’ \(^9\)

1917: Baird, J. W. studied the time taken to find names in a telephone directory. 32 subjects (skilled to unskilled) including telephonists, general clerks and business men were observed both in natural and artificial lighting. A name was spoken or

shown to the subject who had to find corresponding numbers and speak it aloud. Each subject had 30 exposures in 4 arrangements of print in short sessions to avoid fatigue. The average time taken to find a number on a page (directory) of three columns of text set solid was 10-36 seconds, four columns of text set solid was 10-69 seconds and for four columns set at 1/2 leading was 9-20 seconds. The results showed that four columns leaded page was much more legible than either of the others by 13 per cent.94

1917: Weiss, A. P. studied the degree to which letters can be thrown out of focus (maintaining a constant size) and still be recognised.

1917: Kirschmann studied eye-movement during reading and found that there is no correlation between the number of eye-movements and the degree of fatigue and that fatigue in reading is correlated with a lack of variety of distance between the points of fixation.

1918: Judd, C. H. looked at the size of type and legibility by a kinetoscopic photography of eye movement. He used three type sizes 22pt, 11pt and 4.5pt (?) with six lines of narrative read silently by three graduate students, based on duration and number of eye-pauses. From this he concluded:

The rate of reading and span of recognition are only slightly altered by doubling or halving the body-size of a face. Slightly more influence was exerted by halving than by doubling the size.95

1921: Bentley, M. studied the time taken to read a given amount of type (aloud).

Bentley’s definition of legibility of a typeface is the ability to read quickly and easily.96

1921: Bentley, M. determined the effect of ten different amount of leading upon legibility of three type sizes at various distance. Unleaded material was read relatively slowly and reading rate increased with additional leading up to 7 point and than rapidly declined.97

1922: Hartridge, H., and Owen, H. B. looked at the legibility of letters by reading characters and recording errors at different distances. Finding in descending order of legibility: LAJENHXPFZUDYVKCBORS.98

1922: Parsons, J. H. study of the contrast of thickness and thinness of limbs found that up to a point increasing contrast diminishes visibility but increases legibility, for

---

95 Ibid., p103.
96 Ibid., p68.
though a thin line may be harder to see as part of a character design it may
increase individuality and therefore increase legibility.\textsuperscript{99} While looking at type
size by amount grasped by eye per glance he concluded that condensed letters
have an advantage.\textsuperscript{100}

1922: Legros again studies legibility coefficient and specific legibility with typefaces.
While looking at margins and the effect on legibility he outlined that a white
space should logically form the boundary between adjacent area of print, and also
was in favour of a slightly wider margin where a metal rule would otherwise be
considered necessary.\textsuperscript{101} Legros also studied serifs and legibility and concluded:

The idea that the serif is a mere ornament and not an integral feature of the
familiar typeface used for ordinary reading matter… is far from being the
case. The absence of serifs actually increases the resemblance between
several sorts, e. g. i and l. Moreover, in square sorts, e. g., m, n, u, i, l, the
presence of the serif ensures the provision of adequate white between the
main-stroke of adjacent characters. Excessive thickness of the serif (as e. g.
in French Clarendon) does not tend to increase legibility.\textsuperscript{102}

1922: Updike, D. B. looked at typefaces and concluded that Modern typefaces appear at
first sight clearer to the eye and more easily read than old style but they are really
less so in the long run, also modern typeface is admirable for books of a scientific
or technical character.\textsuperscript{103}

1923: Burtt, H., and Basch, C. studied the degree to which letters can be thrown out of
focus (maintaining a constant size) and still be recognised.

1923: Morison, S., and Jackson, H. studied the length of lines by aesthetic appearance
solely and presumably. Finding that eight to ten words per lines are best and
double columns should be used when more than 14 words occur per line.\textsuperscript{104}

1924: Lyon, O. C. studied the time taken to find names in a telephone directory and the
judgments of 300 subjects as to the legibility of pages in telephone directory.
Found that there was no measurable difference between 6pt solid and 6pt on 7pt
leading. The 6pt on 7pt leading had greater aesthetic appeal and was generally
preferred.\textsuperscript{105} As part of this experiment the appearance of the paper and ink were
taken into account resulting with (i) there was no difference between a white

\textsuperscript{99} R. L. Pyke, \textit{The Legibility of Print} (Special Report Series, No. 110. Medical Research Council. London: His Majesty’s Stationery
Office, 1926), 65.
\textsuperscript{100} Ibid., p104.
\textsuperscript{101} Ibid., p93.
\textsuperscript{102} Ibid., p101.
\textsuperscript{103} Ibid., p75.
\textsuperscript{104} Ibid., p92.
\textsuperscript{105} Ibid., p84.
paper and four shades of buff-coloured newsprint and (ii) the white paper has
greatest aesthetic appeal, and preferred generally.106

1924: Morison, S. studied the contrast of thickness and thinness of limbs from an
aesthetic judgment as to ‘compactness of appearance of whole page and in general
terms legibility and came to the opinion: ‘Opposed to “excessive” contrast.’107 In
his study on type size by aesthetic and compactness of appearance of the whole
line and or the page, Horison concluded that the upper case should be slightly less
high than the lower case ascender.108

1924: Pratt, C. C. studied the time taken to find figures (i.e. dates) and letters.

1925: Kerr, J. studied typefaces and concluded that Latin type has more legible letters
than Fraktur, but is unwilling to reject altogether the idea which was popular at
the time with some German writers that Fraktur makes more easily recognised
and characteristic whole words. Kerr also found that sans serifs letters would
seem the best but owing to irradiation are not as legible as letters with thicker
ends.109 He also looked at paper by glare and strain on children’s growing eyes.
Advising for the avoidance of glare the paper must be without gloss, so hard as to
take a clean impression and not to be easily dirtied. It must be thick and opaque
enough to prevent any shining through and not allow the pressure of types on the
reverse side to mar the smoothness of the surface.110

1925: Banister, H., Hartridge, H., and Lythgoe, R., looked at the legibility of letters
with two methods. Method 1: the number of mistakes made in the recognition of
the letters with prolonged observation, the letters at the eye making only a small
angle. And method 2: the number of errors made in tachistoscopic exposure. Both
methods looked at uppercase characters. Resulting in descending order of
legibility. Method 1: LJIAPTZFUEDXCNHKOWYRBMQSGV and for
Method 2: JLPZEFDATUNHKBCIRWYSXOMVGQ.111

1926: R. L. Pyke’s experiments as part of his report ‘to select the best faces of Type
and Modes of Display for Government Printing’ working in the Psychological
Laboratory, University of Cambridge, under the direction of Mr. F. C. Bartlett.112
Experiments: Series A, B, C, and D

Office, 1926), p97.
107 Ibid., p65.
108 Ibid., p104.
109 Ibid., p104.
110 Ibid., p98.
111 Ibid., p89.
112 Ibid., preface.
These series were intended to compare (1) the effect of a normal with a low illuminated on the reading performance, and (2) the difference in the legibility of the three standard styles: Old Style, Old Face, and Modern Face. 

Experiments: Series 1–8
The purpose of Series 1-8 was (i) to re-test in better controlled conditions the three standard styles used in Series A, B, C, and D, and (ii) to test in conjunction with (i) the comparative legibility of five sorts of faces, each embodying a distinct and an important quality viz:
1. Lateral extension of faces.
2. Lateral compression of faces.
3. Uniform thickness of limbs.
4. Uniform thinness of limbs.
5. Absence of serifs.

Experiments: Series 9
The object of this series was to find out if tests of a totally different and less elaborate sort would confirm the results of Series 1–8.

Experiments: Series 10
This was a rough attempt to corroborate in a different was Series 1–8, to discover a more realistic test than by using nonsense, and to utilize sense material by testing every type at every session eliminating influences due to differences in the position of the type by revolving their order.


1938: Alderman, E. ‘The Effect of Size of Type on Speed of Reading and the Determination of Various Factors that May Influence the Results.’ Published: The Pittsburgh Schools, pp. 33-36, November and December. For all groups and all variables, smaller type was read faster than larger type.

1938: Woodworth, Robert, S. found that word shape model is that lowercase text is read faster than uppercase text.

1939: Bell, H. M. in the paper ‘The Comparative Legibility of Typewriting, Manuscripts and Cursive Script: I. Easy Prose, Letters and Syllables’ published: Journal of Psychology, October 1939. The results were that typewriting was read significantly faster than manuscript and cursive script except for 1 and 3-syllable non-sense words in manuscript also manuscripts were read faster than cursive script except for alphabet letters where cursive was read faster.

1939: Bell, H. M. in the second paper: ‘The Comparative Legibility of Typewriting, Manuscripts and Cursive Script: II. Difficult Prose and Eye-movement

---

114 Ibid., p.47.
115 Ibid., p.54.
116 Ibid., p.56.
Photography’ published: Journal of Psychology, October 1939. This was investigated by means of eye-movement photography and the results showed that typewriting was read more rapidly than cursive script, and manuscripts were read as rapidly as typewriting, and also that manuscripts was read more rapidly than cursive script.118

Miles Albert Tinkers’ publication Legibility of Print 1963 gives a comprehensive survey of the problems encountered in measuring and evaluating legibility. The following are some of the factors and dates of research by Tinker in the field of typography and were published in the Journal of Applied Psychology. Material and dates from Sandra Wright Sutherland paper “The Forgotten Research of Miles Albert Tinker” published in the Official Journal of the International Visual Literacy Association, Inc., 1989, Vol. 9, No 1 pages 10-25.119

1928: Type from (lowercase vs. all caps vs. italics)
1929: Length of line (9, 13, 17, 21, 25, 29, 33, 37 picas)
1931: Simultaneous variation of type size and line length (6 pt. 16 picas. 8 pt. 17 picas, 10 pt. 19 picas, 12 pt. 23 picas, 14 pt. 27 picas)
1931: Black type versus white type
1931: Variations in colour of print and background
1932: Leading, or interline spacing (set solid, 1 pt., 2 pt., 4 pt.)
1932: Styles of typeface (Scotch Roman, Garamond, Antique, Bodoni, Old Style, Caslon, Kabel Lite, Cheltenham, American Typewriter, Cloister Black)
1936: Printing surface (Eggshell, Artisan enamel, Flint enamel)
1928: Numbers versus words
1928: Relative legibility of letters, digits and mathematical signs
1930: Relative legibility of Modern and Old Style numerals
1932: Colour of print and background
1938: Part-whole proportion illusion in printing
1942: Reader preference and typography
1943: Comic books
1944: Criteria for readability

1946: Yearbook typography
1943: Newspaper body type
1944: Wartime changes in newspaper body type
1946: Newspaper type (line width and leading)
1946: Newspaper and book print
1947: Newspaper type (leading)
1963: Simultaneous variation in size of type, width of line and leading for newspaper type
1935: Typography for children
1953: Size of type in primary grades
1959: Print for children’s textbooks
1963: Legibility of print for children in the upper grade
1948: Marginal conditions
1948: Blink rate (book print and newsprint)
1949: Nine point type and line width and leading
1952: Vibration effects with 6pt type
1954: Slanted text
1955: Vertical vs. horizontal arrangements
1955: Typographical variations
1956: Angular alignment
1956: Sloped text
1957: Curved text

**Eye movement, influence of:**

1939: Type form
1940: Line width
1941: Modern typefaces and Old English
1942: Size of type
1942: Line width for six point type
1944: Optimal and non-optimal typography
1944: Black print on white, red on dark green
1955: Vertical and horizontal arrangements
1955: Typographical variations
1957: Colour of print and background
Illumination, for reading:
1943: Newspaper type
1952: Six point type

Books:
1940: How to Make Type Readable (with Donald Paterson Harper Brothers: NY)
1963: Legibility of Print (Iowa State University Press, Ames, Iowa)

1940: C. E. Ferree & G. Rand. ‘A convenient and practical means for studying light and color minima in any part of the retina’ *Journal of Experimental Psychology* 26 (1): 28 (1940). They found that colour combination with a high brightness contrast give the best legibility. An attachment to the Ferree-Rand perimeter for determining light and colour minima in any part of the field of vision is described. Preliminary determinations of minima made with the attachment show sensitivity gradients for light and colour from centre to periphery and variations in these gradients may be due to pathologic disturbances and other causes.120

1944: Berger, C. published ‘Stroke-width, Form and Horizontal Spacing of Numbers as Determinants of the Threshold of Recognition’ in August and July 1944 *Journal of Applied Psychology*. Vehicle license plates were studied by the recognition of numbers with certain typographical variations. The results showed that white numbers on black 6 millimeters was the optimal stroke width, and for black numbers on white 10 millimeters was optimal. Single white numbers were 8.2% more recognisable than optimally constructed black numbers of the same area.121

1947: Carmichael & Dearborn: studied visual fatigue — the subjects were at their tasks for six hours and recordings were made of their eye movement. The results seem to show surprisingly little evidence of increased fatigue that is exclusively attributable to reading during such a long period.

1948: Anderson, I. H., and Meredith, C. W.: studied the effects of reading microfilm versus printed material and the surrounding light on visual fatigue and the rate of reading. The average rate of reading projected by microfilm was 12% slower than that for printed material. No evidence of fatigue was found for either typefaces of material. Microfilm was read more rapidly without surrounding light. Published: *Journal of Educational Research*, February, 1984, pp. 453-60.122

122 Ibid., p267.
1948: Woodworth confirmed the Erdmann–Dodge (1897) theory that reading takes place during the fixation-pause and that the eye sees little or nothing while moving.

1948: Wilkins questioned the recognisability of words by investigating combinations of letters, prefixes and suffixes by mixing up familiar words such as Woodson, Wilrow, which would be recognised at a speedy glance as Woodrow Wilson, thus demonstrating the importance of word-fraction reading.123

1954: Miller & Bruner substantiated Cattell 1885 findings that the eye could grasp the whole word as quickly as a letter and that sense material or sense words were read at a greater speed than nonsense material.

1959: Edfeldt used electromyography to show that silent speech is a fact. He also demonstrated that factors such as difficulty of text and reader ability were correlated with the strength of silent speech.124


1963: Sperling, G. ‘A Model for Visual Memory Tasks’ studied letter recognition and he found that letters could be recognised at a rate of 10-20ms per letter.125

1965: Bror Zachrisson publication covers the following experiments:
The following covers experiments in 1954 and 1964.
Experiments regarding familiarity with typographical elements
Exp. 1, Response to type faces
Exp. 2, Recall and reproduction of letters
Exp. 3, Preferences

Experiments in the Reading of running text and isolated words

*Type Design*

Exp. 4, Oral reading
Exp. 5, Silent reading

124 Ibid., p32.
Exp. 6, Tachistoscope
Exp. 7, Focal variator
Exp. 8, Perimeter
Exp. 9, Binocular rivalry
Exp. 10, Reader’s opinion

Type Size
Exp. 11, Oral reading
Exp. 12, Silent reading
Exp. 13, Reader’s opinion

Typography
Exp. 14, Division of text
Exp. 15, Even and uneven lines

Experiments regarding congeniality
Exp. 16, Evaluation of typographical solutions
Exp. 17, Knuttel’s pairs

1969: Reicher, replicated James Cattell’s study (1886) supporting word shape. He presented strings of letters for a brief period — half the time real words, half the time not real words. The subjects were asked if one or two letters were contained in the string, for example D or K. Reicher found that subjects were more accurate at recognising D when it was in the context of WORD than when in the context of ORWD. This supports the word shape model because the word allows the subject to quickly recognise the familiar shape.126

1969: Smith confirmed Woodworth, Robert, S. (1938) findings that word shape model is that lowercase text is read faster than uppercase text.

1971: Bouma, H. ‘Visual recognition of isolated lower-case letters’ published in the Vision Research, 1971, 11, 459-474. He studied the recognition and confusion of lowercase alphabet in two studies ‘using different technique to control average correct performance to 0.50—one a long viewing distance and the other eccentric (nonfoveal) presentation’.127


---


1972: Gough proposed the model of word recognition which claims that words are read letter-by-letter, because it was easy to understand and more testable than the word shape model of reading. ‘You start off by finding the first letter, than the second, and so on until you recognise the word.’

1975: Fisher confirmed the findings of Woodworth, Robert, S. (1938) that word shape model in lowercase text is read faster than uppercase text.

1977: Alyson L. Hill, Department of Psychology, Stephen F. Austin State University carried out research into ‘Readability Of Websites With Various Foregrounds / Backgrounds Color Combinations, Font Types and Word Styles’.

1984: Kruk Richard S. and Muter Paul. “Reading of Continuous Text on Video Screens” Human Factors, 1984, 26, (3), 339-345. In three experiments The Human Factor Society, Inc. found that slower reading of text from a video screen than from a book was replicated, and several possible reasons for this effect were explored.


1995: Tullis, Thomas S., Boynton, Jennifer L., and Hersh, Harry. ‘Readability of Fonts in the Windows Environment’. The readability of twelve typefaces and sizes in the Microsoft Windows environment were studied, with specific typefaces such as Arial, MS Sans Serif, MS Serif and Small typefaces with size ranging from 6pt to 9.75pt.

2001: Software Usability Research laboratory Wichita State University carried out a study entitled ‘A Comparison of Popular online Fonts: Which are Best and Why’


by Michael Bernard, Melissa Miles, Michelle Peterson and Kelsey Storrer. A general survey was carried out on the web.


Text readability was measured for two types of transparent text (additive and multiplicative) at two contrast levels (0.3 and 0.45) on three background textures (culture, wave, plain), and it was measured for five levels of low text contrast (0.1, 0.15, 0.2, 0.25, 0.3) on plain backgrounds. For the transparent text, reading search times were longer for additive transparency, the low contrast, and the culture then the wave and then the plain background. For the low contrast experiment the 0.1 contrast level led to significantly slower search times when compared to all other contrast levels. When there were background textures a masking index that combined text contrast and background RMS contrast predicted search times much better than either measure alone. When the masking was adjusted to include the text pixels as well as the background pixels in computations of mean luminance and contrast variability, predictability improved further.132

2007: Silvia Zuffi (ITC, Consiglio Nazionale delle Ricerche, Milano, Italy), Carla Brambilla (IMATI, Consiglio Nazionale delle Ricerche, Milano, Italy), Giordano Beretta (Hewlett-Packard Laboratories, Palo Alto, USA), Paolo Scala (ITC, Consiglio Nazionale delle Ricerche, Milano, Italy), ‘Human Computer Interaction: Legibility and Contrast’.

2010: Nguyen, B. and Chaparro, B., online survey exploring iPad usage ‘iPad is Best for Reading, Communicating, and Gaming.’ Usability News, November 2010, Vol. 12 Issue 2, produced by the Software Usability Research Laboratory (SURL) at Wichita State University.133

2012: Bessemans, A., researched how people, especially children with low vision, read typography and how this is affected by the design of typefaces and developed a typeface Matilda, that was developed as a result of the research.


Readability Studies

There are various concepts of readability. Jeanne S. Chall (1958) states in his publication *Readability an Appraisal of Research and Application*: ‘The term readability has no standard meaning.’134 He goes on to point out that readability can be seen as readability as legibility; readability as interest; and lastly readability as ease of understanding. The following is a list of studies from 1921 to 1958 which consider these factors of readability, and are sourced from Chall 1958 publication and George R Klare and Byron Buck 1954 publication *Know Your Reader*. ‘In the 1920s, educators discovered a way to use vocabulary difficulty and sentence length to predict the difficulty of a text — the level of reading skill required to read it.’135 The methods ‘readability formulas’ have proven their worth in over 80 years of research and application.

1893: L.A. Sherman ‘gave the world a new method of literary criticism’136. Sherman was one of the first to recruit science to advocate an ‘objective’ approach to literature in 1893 he published *Analytics of Literature: A Manual for the Objective Study of English Prose and Poetry*.

1906: Dearborn studied eye movement by means of photography of a pencil of light reflected from the cornea for silent reading and eye movement and indentation. Dearborn’s judgment was opposed to it especially for children as it upsets the motor innervation rhythm.137

1913 Hollingworth, H. J. looked at the colour of text and paper and came to the conclusion that ‘so far as acuity and legibility go there is no difference between the arrangement of white letters on a black ground and black letters on a white ground’138 but he has a preference for black text on white for the reason white is associated with space and blankness and black with objects, thus black letters are better than white.

---

135 Ibid., p1.
137 Ibid., p96.
1913: Pintner: contested the prevalent view that silent reading is accompanied by ‘silent speech’. By experimenting with the simultaneous reading of different text Pintner introduced doubts as the prevalence of ‘silent speech’.

1915: Jerkins, F. looked at the length of lines and the strain on a child’s growing eye by studied margins and concluded that the inner margin of the page should be wide enough so that when the book is open troublesome shadows are not seen, and words are not distorted by the curve of the inner part of the page.139

1917: Clarence Trumangray for the General Education Board in the University of Chicago, carried out extensive tests into reading ability (both oral and silent reading) of elementary and high school students between the years 1914 and 1916.140

1920: Berkowitz, J. H. studied the illumination for typography by intensive survey of conditions in the U.S.A. and questionnaires over an extensive field in the U.S.A. The conclusions for schools (i) area of windows should be 1/4 to 1/5 that of the floor. (ii) They should be placed on one side of the classroom so that the light would fall upon the writing surface of the desk from the left side of the pupil. (iii) There should be uniform light distribution, both natural and artificial and (iv) there should be no glare.141

1920: Caldwell, F. inspected schools in U.S.A. and reviewed previous work in the study of illumination of type and the strain on children’s eyes tending to cause myopia and agreed with Berkowitz (1902) findings.142

1921: Harry D. Kitson published a method of measuring the readability of adult material by the (i) syllables per word and (ii) sentence length in words. ‘This is a comparison method rather than a true formula; it is interesting, however because at the early date of 1921 the same elements were used in Flesch’s recent [1943-1950] “reading ease” formula.’143 Kitson in 1921 published The Mind of the Buyer: A Psychology of Selling.

1921: Edward L. Thorndike published the first listing of words in English by frequency of use in The Teacher’s Word Book, which listed 10,000 words by frequency of use.

140 Clarence Trumangray, Types of Reading Ability, as Exhibited through tests and laboratory experiments an investigation subsidized by the General Education Board (First published 1917, reprint 2013 in India by Isha Books, B-69, New Gupta Colony, New DDA Market, New Delhi – 110009), 18-19.
142 Ibid., p78.
1921: Luckiesh, M., Taylor, A. H, and Sinden, B. H. studied the speed of reading and illumination. They found that the speed of reading increased with an increase of artificial illumination from 0.4 to 25 foot-candles. The rate of increase in speed diminished throughout. With an illumination of 5 foot-candle the speed of reading was 10% greater than with one of 4 foot-candles.\textsuperscript{144}

1921: Wood, F. H. studied the day lighting in schools and found that (i) windows should be grouped on the left of students as seated and directly opposite their desks, none reaching beyond the front desks. (ii) Windows must extend to the ceiling and (iii) windows must have a minimum area equal to 1/5 of the floor space\textsuperscript{145} (similar findings to Berkowitz in 1920 and Caldwell in 1920)

1923: Bertha A. Lively and S. L. Pressey published the first quantitative study into readability. The study set out to determine the vocabulary difficulty of textbooks because teachers reported an unusual number of technical terms in junior-high school science books. ‘This is the first children’s formula developed.’\textsuperscript{146}

1924: Illuminating Engineering Society inspection of schools for illumination and concluded that (i) the day lighting should be so arranged that pupils are compelled to face windows and (ii) for artificial lighting the light at the desk surface should be not less than 5 but at optimum 10 foot-candles.\textsuperscript{147}

1926: Carleton W. Washburne and Mabel Vogel carried out significant studies into readability at the Winnetka, Illinois schools. This research included about thirty-seven thousand children. The study set out to determine what books were read and liked in certain grades.

1927: Keboch carried out a quantitative study into readability to find the variability in social studies with 45-pages samples from five American history text books in grade VII students.

1928: Carleton Washburne and Mabel Vogel in Winnetka carried out a quantitative study into readability with 1,000-word samples from 150 books, mainly fiction, from children’s library books with students of grade III to IX to find the average reading ability. The method used: ‘score on paragraph meaning section of Stanford Achievement.’\textsuperscript{148} This formula ‘is the prototype of modern readability

\textsuperscript{144} R. L. Pyke, \textit{The Legibility of Print} (Special Report Series, No. 110. Medical Research Council. London: His Majesty’s Stationery Office, 1926), 78.

\textsuperscript{145} Ibid. p79.


\textsuperscript{148} Jeanne S. Chall, \textit{Readability: An Appraisal of Research and Application} (Columbus Ohio: The Bureau of Educational Research Ohio State University, 1958), 36.
1929: Lewerenz carried out a quantitative study in readability with mostly non-fiction paragraphs from reading sections of the ‘Stanford Achievement Test’, and also difficult passages from John Dewey were conducted using students at grade II up to and including college level.

1930: Johnson carried out a quantitative study into readability with Primer to Grade VIII using elementary textbooks and standardised tests for elementary school, Thorndike word list.

1931: W. W. Patty and W. I. Painter carried out a quantitative study into readability ‘A Technique for Measuring the Vocabulary Burden of Textbooks’ with textbooks in English on social studies, science and mathematics. The material used was the third line of every fifth page of high-school textbooks. ‘This formula determined the relative difficulty of textbooks using a combination of frequency as determined by the Thorndike list and vocabulary diversity.’

1931: Douglas Waples and Ralph W. Tyler published What People Want to Read About. This was a two-year study of adult reading interests.

1932: Edward L. Thorndike published his second listing of words in English by frequency in The Teacher’s Word Book of 20,00 Words.

1934: Edgar Dale and Ralph W. Tyler study involved an investigation into factors with adults with a limited reading ability. The study focused on material designed specifically for adults with limited reading ability. ‘Interesting in that it is one of first true formulas for adults though actually for low-ability readers.’

1934: McClusky carried out a quantitative study into readability with the rate of reading by 30 college students using 6 sections from 580 to 919 words each from reading material in fiction, political science, economics, sociology, psychology and physics.

1934: Ralph H. Ojemann ‘The Reading Ability of Parents and Factors Associated with Reading Difficulty of Parent Education Materials,’ reported a method of judging the difficulty of parent-education materials. This included both quantifiable and qualitative factors.

1934: Thorndike carried out a quantitative study into readability and the difficulty

---

postulated by percentage of words unknown to children in various grades using material of 10,000 to 20,000 word samples from books for Grade IV to IX.

1935: William S. Gray and Bernice E. Leary published *What Makes a Book Readable*, and contain two surveys of opinion on readability. The first survey by William S. Gray and Bernice E. Leary indicated a general agreement among librarians, teachers, and publishers that factors of content were more important than those of style, format and organisation (in that order). ‘Because of its completeness, Gray and Leary’s work has been one of the landmarks in the study of readability.’

1935: The second survey by Ruth Strang reported on what makes a book readable for high-school and college students. The survey showed that high-school students wanted ‘plain everyday English,’ ‘easy simple vocabulary,’ and ‘short paragraphs and sentences’ and they said that aided readability. The college students had similar views except that factors of organisation were given more weight ‘principles given without explanation,’ and the ‘discussions of topics without telling anything of its background,’ and ‘too many thoughts on a page.’

1935: Elizabeth C. Morris and Dorothy Holversen developed an ‘idea analysis technique’ in conjunction with the Readability Laboratory at Teaching College, Columbia University.

1936: Cassie Burk study compared direct conversation and indirect conservation. Burk’s material for the experiment was the re-writing of three stories in nine different ways. He found some indications that the children (fourth-grade pupils) preferred the stories consisting of direct conversation and that the average comprehension and reading rate was higher for these stories.

1938: DeLong carried out a quantitative study into readability with material of 27 pre-primers, 34 primers, 44 first readers and 28 second readers for Pre-primer to Grade II.

1938: Stone carried out a quantitative study into readability on school reading books Grade I.

1938: Washburn and Morphett carried out a quantitative study into readability the same as the Winnetka 1928 study but with the range of difficulty Grade I to II the method used was by combination of teacher judgment and reading by children.

---

154 Ibid., p15.
‘This is one of the most used children’s formulas.’\textsuperscript{155}

Washburne-Morphett formula comprised of the following:

\begin{itemize}
\item \textit{Systematically selected} samples of 1000;
\item \textit{Count} the number of different words ($x_1$);
\item \textit{Count} the number of different uncommon words (not in Thorndike’s first 1500) ($x_2$);
\item \textit{Count} the number of simple sentences in 75 sample sentences ($x_3$);
\item \textit{Apply} in the formula:
\end{itemize}

\begin{equation}
X1 \text{ (grade placement)} = 0.00255x_2 + 0.0458x_3 - 0.0307x_4 + 1.294\textsuperscript{156}
\end{equation}

1938: Irving Lorge published \textit{The Semantic Count of the 570 Commonest English Words}, a frequency count of the meaning of words rather than the words.

1939 and 1944: Irving Lorge sought for a simple empirical formula that could be used. Lorge began his search by computing a series of multiple correlations between various combinations of Gray-Leary factors and McCall-Crabbs test scores the formula that resulted was as follows:

\begin{itemize}
\item \textit{Compute} average sentence length in words ($x_2$);
\item \textit{Compute} number of prepositional phrases per 100 words ($x_3$);
\item \textit{Count} number of different hard words per 100 words not on the Dale 769 word list ($x_4$);
\item \textit{Substitute} in the formula:
\end{itemize}

\begin{equation}
X1 \text{ (grade placement)} = 0.07x_2 + 0.1301x_3 + 0.1073x_4 + 1.6126\textsuperscript{157}
\end{equation}

In 1939 Lorge published an article ‘Predicting Reading Difficulty of Selections for children’, and demonstrated that new combinations of variables gave predictions of higher accuracy than the Gray-Leary formula.\textsuperscript{158} In 1944 Lorge published his new Lorge Index in the \textit{Teaches College Record} in an article ‘Predicting Readability’.

1940s: Rudolf Flesch worked with the Readability Laboratory at Teaching College, Columbia University in relation to the readability of non-fiction books by the average adult reader. Flesch was the only researcher in readability to turn his studies into popular books in 1946 \textit{The Art of Plain Talk} and in 1949 \textit{The Art of Readable Writing}.

1943: Flesch measured the readability of adult’s materials by the average sentence length in words: (ii) number of affixes and (iii) the number of personal references.

‘The first Flesch formula, since super-seded.’\textsuperscript{159}

\begin{footnotes}
\item\textsuperscript{156} George R. Klare, \textit{The Measurement of Readability} (Ames, Iowa, USA: Iowa State University Press, 1963), 52.
\item\textsuperscript{157} Ibid., p54.
\item\textsuperscript{158} William H. DuBay, \textit{Unlocking Language, The Classic Readability Studies} (Costa Mesa, California: Impact Information, 2007), 166.
\end{footnotes}
1944: Edward L. Thorndike published his listing of words in English by frequency of use in *The Teacher’s Word Book of 30,00 Words*. Irving Lorge was co-author in this publication.

1948: Edgar Dale and Jeanne S. Chall’s second most widely used adult formula was applied to both children and adults work and the elements used to measure readability were (i) average sentence length in words and (ii) Dale score; that is words nor on Dale List of 3000. The disclaimer Dale-Chall published with their formula, ‘we do not claim this formula developed here is definitive. The nature of the multiple-correlation coefficient makes this point rather obvious. We do believe, however, that it is a short cut in judging the difficulty of writing materials.’ (The Dale-Chall readability formula arrived at the end of a national research effort that began in 1920s and that eventually resulted in over a thousand published studies on the readability formulas.)

1948: Dolch measured the readability of children’s materials by the then newest of children’s readability formulas by (i) average sentence length in words; (ii) ‘long sentence’ length (upper tenth of sentence lengths) and (iii) percentage of words not in Dolch’s *First 1000 Words for Children’s Reading*.

1948: Rudolf Flesch again measured the readability of adult material by the average sentence length in words and the average word length in syllables. ‘This is the most widely used of all readability formulas, and is used in both children’s and adult work.’ It was published in an article ‘A New Readability Yardstick’ in the *Journal of Applied Psychology*, Vol. 32, No. 3, 3 June, 1984

Flesch formula consisted of the following:

Systematically selected samples of 100 words throughout the material to be rated;

Compute average sentence length in words ($x_s$);

Count the number of affixes ($x_m$);

Count the number of personal references ($x_h$);

Average the results and insert in the formula:

$$0.1338 x_s + 0.0645 x_m - 0.0659 x_h - 0.7502$$

Flesch’s work was based partially on some of Lorge’s computations and a later correction was necessary to correct an error in Lorge’s data giving a final formula:

---


163 Ibid., p103.
\[0.07x_m + 0.07x_s - 0.05x_h + 3.27^{164}\]


1948: Mary C. Wilson carried out an experimental study using social-studies material designed to show the effect of increase on the reader’s comprehension. The results showed that a century and a half of history produced in over a page and a half resulted in an ‘x’ amount of comprehension. Wilson showed that when this page and a half was expanded by the addition of important details, explanations and examples, children got more from the text without simplifying the vocabulary or sentence structure.

1949: Edgar Dale and Jeanne S. Chall produced a comprehensive definition of readability for investigations in ‘The Concept of Readability’.

1950: Flesch measured the readability of adult material in an ‘attempt to get at abstractness of writing’\(^{165}\) by counts of sixteen categories of ‘definite’ words and average word length in syllables.

1951: McElroy developed a formula to measure the readability of adult material with the elements; (i) give each ‘easy’ element in sentence a value of 1 and (ii) give each word that is left a value of 3. This formula has been licensed to agencies of the U.S. Government and is not publicly available.\(^{166}\)

1951: Farr, Jenkins and Paterson’s formula has been found to be somewhat faster in application than the Flesch formula on which it was based. The elements used for this formula were (i) the number of one syllable words per 100 words and (ii) average sentence length in words.

Farr-Jenkins-Paterson’s formula consists of the following steps:

- **Systematically** select 100-word samples from the material to be analyzed;
- **Determine** the number of one-syllable words per 100 words (nosw);
- **Determine** the average sentence length in words (sl);
- **Apply** in the formula:

\[
\text{New Reading Ease Index} = 1.599\text{nosw} - 1.015\text{sl} - 31.517^{167}\]

1952: Gunning’s formula ‘probably gives results closely related to Flesch’s 1948 formula’.\(^{168}\) The elements used were the number of words of three or more syllables in 100 words and (ii) average sentence length in words.

\(^{165}\) Ibid., p103.  
\(^{166}\) Ibid., p103.  
Gunning’s formula consists of the following steps:

*Take* systematic samples of 100 words;
*Divide* number of words by number of sentences to get sentence length;
*Count* the number of words of three or more syllables (with certain exceptions) to get percentage of hard words;
*To get the Fog Index, total* the two factors above and multiply by .4.\(^{169}\)

1953: Spache carried out a quantitative associational study into readability on the material of 224 samples of 100 words from 152 primary-grade textbooks with the percentage of hard words (outside Dale 769) with average sentence length.

1963: Edward Fry’s original graph determines readability in High School. It was validated with comprehension scores by using primary and secondary school materials and by correlations with other formulas. ‘Edward Fry’s Readability Graph may be the most popular readability aid.’\(^{170}\)

The Fry’s graph worked on the following:

1. Select samples of words.
2. Find y (vertical), the average number of sentences per 100-words passage (calculating to the nearest tenth).
3. Find x (horizontal), average number of syllables per 100-word sample.
4. The zone where the two coordinates meet show the grade score.\(^{171}\)

1967: Jeanne Chall published *Learning to Read: The Great Debate*. Chall led the battle for teaching early reading systematically with phonetics.

1975: George W. McConkie and Keith Rayner experiment proved that we only see a very small part of each page at a time. McConkie and Rayner designed a ‘moving window’ that creates an illusion of text on a computer screen. The voluntary eye movement was tracked and the visible display was changed in real time. The device can be programmed to display only a few characters left and right of the centre of gaze and the remaining letters were replaced with x’s.\(^{172}\)

1981: Kak, Anita V., ‘Relationship between Readability of Printed and CRT-Displayed Text’ Proceedings of the Human Factors and Ergonomics Society Annual Meeting 1981 25:137 (investigated by implementing a computer-display version of the Nelson-Denny Reading Test). The results suggested that standard legibility measured (e.g., scanning rate) may be inappropriate criteria in evaluating CTR display in more usual reading tasks.\(^{173}\)

---


\(^{171}\)Ibid., p83.


1982: Muter, P., Latremouille, S. A., Treurniet, W. C. & Beam, P. published their study ‘Extended reading of continuous text on television screens’ in the Human factors, 24(5), 501-508.). In the study subjects read white text on a blue background, with the subject being approximately 5 m from the screen. The characters, displayed in teletext format on a television, were approximately 1 cm high, and time to fill the screen was approximately 9 seconds. The book used was one of the large format books prepared for the partially sighted, and it must assumed that the screen text characters were substantially larger than the printed characters.174

1982 to 1990: Colin Wheildon studied over a nine-year period typographical maxims into elements of design and typography. ‘David Ogilvy more than once raised the question whether I was measuring reading comprehension or merely readability.’175 (Ogilvy started his own design agency in New York in 1984 and built it into one of the largest in the world Ogilvy & Mather Worldwide) Topics covered: Colour, type, reading and the eye (how we see and how we read) and word shape versus letter shape. The subjects, a total of 224 people, drawn from ten Sydney suburbs completed the first programme a series of tests run over a period of five years. All these subjects with the exception of two described themselves as consistent readers of a range of newspapers and other publications and thus were described as fluent readers. The second series of tests started in 1986 included the initial 224 subjects and a further 276 subjects. With further research ‘the flyer study’ carried out in 1988 with the original 224 subjects along with the NRMA backed major study conducted through its Public Relations and Research departments included 15,000 participants. 4,000 sub-sample used for the type size tests were randomly drawn from the 15,000. Non fluent readers and others who may have some kind of vision impairment which include colour blindness are estimated ‘that in nations like the USA, United Kingdom, Canada, Australia and New Zealand, western industrialized nations with universal education’ is between 10 and 20 per cent of the population.176

1983: Wright and Lickorish found that silent reading from screen is significantly slower than reading from paper. Their experiment showed that figures vary according to means of calculation and experimental design, but the evidence suggested a performance deficit of between 20% and 30% when reading from screen.

175 Colin Wheildon, Type & Layout: Are you Communicating or Just Making Pretty Shapes? Additional material by Geoffrey Heard and forward by David Ogilvy (Hastings (now Mentone), Australia: The Worsley Press, 2007), 140.
176 Ibid., p149.
1983: Robert L. Duchnicky and Paul A. Kolers published a paper *Readability of Text Scrolled on Visual Display Terminals as a Function of Window Size*, Human Factors, 25, 6 (1983): 683-692. The study determined that long line length are more efficient than shorter ones, concluding that columns of text should fill up as much screen real estate as possible.\(^\text{177}\)

1984: Gould and Grischkowsky also found that silent reading from screen is significantly slower than reading from paper. Gould and Grischkowsky used greenish text on a dark background. Characters were 3 mm high and subjects could sit at any distance from the screen. They were encouraged to adjust the room lighting level and the luminance and contrast of the screen for their comfort. Printed text used 4 mm characters and was laid out identically to the screen text.

1987: IBM research team: John D. Gould, Lizette Alfar, Vincent Barnes, Rich Finn, Nancy Gischkowsky and Angelo Minuto studied *Reading is Slower from CTR Display than from Paper*, published in Human Factors, 29, 3 (1987): 269-299. The Team isolated and tested variables that affect text on both screen and page, including image quality, typeface and line length to find what was the reason for poor performance of the screen. Resulting in identifying the fault lay in the way text was presented.\(^\text{178}\)

1987: The IBM team of 1987 produced another paper on readability on screen *Reading from CTR Display Can Be Read as Fast as Reading from Paper*, published in Human Factors, 29, 5 (1987): 497-517. The study presented black, anti-aliased typefaces on a light-resolution screen. The team ‘established that design conventions evolved for print effectively translated to the realm of the screen’.\(^\text{179}\)

1989: Smedshammar et al also found that silent reading from screen is significantly slower than reading from paper. Figures vary according to means of calculation and experimental design, but the evidence suggested a performance deficit of between 20% and 30% when reading from screen.

1995: Tullis, Boynton and Hersch, examined differences in reading rates for different typeface styles and sizes in a proof reading task carried out in a Microsoft Windows environment. Participants used Arial, MS sans serif, and MS serif at 6, 7, 8, 9 and 10-pt type sizes. Tullis et al. found no difference in reading speed between the serif and sans serif typefaces; however, they found that the larger

---


9 and 10 point typefaces elicited faster reading times. The study also found that the participants had a greater preference for the sans serif compared to the serif typefaces.\textsuperscript{180}

1998: An interdisciplinary team (Daniel Boyarski, Christine Neuwirth, Jodi Forlizzi and Susan Harkness Regli) at Carnegie Mellon University compared Times Roman with Goergia a serif typeface designed for the screen. Paper published \textit{A Study of Fonts Designed for Screen Display}, CHI 89, 18-23 (April 1998). This study in testing typefaces on the screen revealed conflicts between how users performed and what they said they liked. The team found no objective differences yet the users preferred Georgia, which they judged sharper, more pleasing and easier to read. A second test compared Gergia (serif typeface) with Verdana (sans serif typeface) both of which were designed for screen. Resulting: users expressed a slight ‘subjective preference for Verdana, but they performed better reading Georgia.\textsuperscript{181}

1998: Boyarski, Neuwirth, Forlizzi and Regli evaluated the reading speed of participants using the serif Georgia, Times New Roman, and the sans serif Verdana typefaces. The typefaces were all set at 10-point and the experiment involved participants completing a comprehension test (i.e. the Tinker Reading Speed test). No significant differences in reading speed were found between the typefaces. However, it should be noted that the Georgia and Verdana typefaces were specifically designed for on-screen reading so this may have influenced the results.\textsuperscript{182}

1999: Eric Michael Weisenmiller ‘A Study Of The Readability Of On-Screen Text’: this study examined the readability of four different typefaces and how they affected both reading rate and reading comprehension. The typefaces Georgia, Verdana, (which, according to their designers, optimize on-screen readability) Times, and Arial (both designed for digital output to hard copy) were displayed as treatments both on a computer screen and on paper. The purpose of the study was to determine whether sans serif and serif typefaces optimised for on-screen viewing significantly improve reading rate and reading comprehension.

(Dissertation submitted to the faculty of the Virginia Polytechnic Institute and


State University in partial fulfillment of the requirements for the degree of Doctor of Philosophy).

2001: Bernard, Mills, Peterson and Storrer, tested a range of typefaces for effective reading speed, i.e. reading speed in conjunction with accuracy, and participants’ perception of typeface legibility. Twelve typefaces representing sans serif, serif, and ornate styles were studied. Differences were found for reading time with Tahoma (sans serif typeface) being read significantly faster than Corsiva (ornate typeface). Perceived typeface legibility also showed significant differences across the 12 typefaces with sans serif typefaces being more legible than the ornate typefaces.

2001: Mary C. Dyson, Mark Haselgrove ‘The influence of reading speed and line length on the effectiveness of reading from screen’ published in the International Journal of Human-Computer Studies, Volume 54, Issue 4, April 2001, pages 585-612. Investigate the effects of two reading speeds (normal and fast) and different line lengths on comprehension, reading rate and scrolling patterns. Scrolling patterns are defined as the way in which readers proceed through the text, pausing and scrolling. Comprehension and reading rate were also examined in relation to scrolling patterns to attempt to identify some characteristics of effective readers. They found a reduction in overall comprehension when reading fast, but the type of information recalled was not dependent on speed. They found that a medium line length (55 characters per line) appears to support effective reading at normal and fast speeds and produced the highest level of comprehension and was also read faster than short lines. Scrolling patterns associated with better comprehension (more time in pauses and more individual scrolling movements) contrast with scrolling patterns used by faster readers (less time in pauses between scrolling).

2002: Bernard, Lida, Riley, Hackler & Janzen, compared four sans serif typeface (Arial, Comic, Tahoma and Verdana), and four serif typefaces (Courier New, Georgia, Century School Book and Times New Roman). They found no difference in effective reading speed between the two types and significant differences were found for reading times of the types with the serif typefaces. The experimenters
found that the participants perceived a difference in legibility between the
typefaces of which Times New Roman, Verdana and Georgia were most
legible.\textsuperscript{186}

2012: University of Liverpool A \textit{Literature-Based Intervention for Older People living}
\textit{with Dementia} funded by the Headley Trust. Assessing benefits of Get into
Reading groups for older people in residential care homes and hospitals in
Merseyside and Greater Manchester.\textsuperscript{187}

2012: ‘Reading for Pleasure in Liverpool Schools’. A pilot project, funded by the
University of Liverpool in partnership with Liverpool Children’s Services
(Liverpool City Council), which places undergraduate art students in Liverpool
schools with children struggling emotionally, socially or educationally. This
project was not a narrow literacy improvement programme, but was
an investigation by professionals from the Institute of Psychology, Health and
Society at Liverpool, into the value of reading for pleasure in relation to
children’s well being.\textsuperscript{188}

\textsuperscript{186} A \textit{Comparison of Two Computer Fonts: Serif versus Ornate Sans Serif}. Guest Contributor: Sarah Morrison and Jan Noyes,
\textsuperscript{187} http://www.liv.ac.uk/psychology-health-and-society/research/reading-information-and-linguistic-systems/research-projects/
\textsuperscript{188} Ibid., http://www.liv.ac.uk/psychology-health-and-society/research/reading-information-and-linguistic-systems/research-projects/
Appendix Two

*Graphics showing typographic layout*

*from Benjamin Sherbow’s 1961 publication Making Type Work*

Appendix Two contains pages from Benjamin Sherbow’s 1916 publication *Making Type Work*. Different pages illustrate different aspects of page layout with uneven colour, spacing, letter spacing, word spacing and line spacing, the text on the pages explain the illustrations as Sherbow explains ‘to show by comparative illustrations how much more effective some type arrangements are than others.’

---

PRINTED matter must be more than readable—it must be easy to read. This is particularly true of advertising literature. In that case it is more important to you than to your readers that your printed words be read. It is to your unquestioned advantage to have your printed matter as easy-to-read as thought and skill can make it.

With the right type face chosen and the right size determined, the question of readability is still unsettled. Margins, space between letters, between words and between lines are almost, if not quite, as important.

Some folks think that the setting of a book page of "straight matter" is the easiest thing a compositor does. To my notion it is the severest test of his ability. To do a good job he has to decide questions about spacing with almost every line he sets. And you will realize what that means when we come to talk about spacing a few pages further on.

Consider this page. It is set in a good book face. The size is about right, but the uneven color, the lack of leads and the inequality in letter and word spacing make it harder to read rapidly and also less pleasing to the eye than the page opposite.

Figure 50: Page 86 from Benjamin Sherbow’s 1916 publication, Making Type Work, showing uneven colour, caused by uneven letter and word spacing.
SPACING

Spacing is probably the most difficult problem in type arrangement. It is the last thing anyone ever learns to do well. Every piece of type composition has its peculiar problem to be worked out and I cannot hope to tell you how to solve them all. I will try only to indicate the purpose of spacing and how its right use helps to get attention for advertising print, makes it easy-to-read and easy to understand.

By spacing I mean the placing of pieces of type metal of varying degrees of thickness between single letters of type, between words, between lines and between paragraphs.

LETTER SPACING

What makes these two words letter spacing look so different from the other words in the same line? It is because I have placed spaces between the single letters while there are no spaces between the letters in the other words.

Does this letter spacing serve any useful purpose? It is often used to avoid a bad break in a word at the end of a line. But that excuse for letter spacing is not good enough. Look at page 86 where I have purposely used letter spacing to demonstrate that it makes print hard to read. And that is a good enough reason for avoiding it. Get as good word spacing as you can, but when you have to choose between letter spacing and wider word spacing, put the space between the words.

Figure 51: Page 88 from Benjamin Sherbow’s 1916 publication, Making Type Work, showing spacing and letter spacing.
WORD SPACING

When words are spaced as in this paragraph, it is like setting each word off by itself to be looked at separately. That makes reading more difficult. And when words are wide spaced in one line and close spaced in the next, the reader may not know just what is the matter, but he knows that the print is not so easy-to-read as it would be if set as in the following paragraph.

The closer spacing of the words in this paragraph not only makes a sightlier page but also makes print easier to read. And it really saves space to set words reasonably close—space that you can use to better advantage between lines of type. Note for instance, the difference between the two lines that follow:

First and last make it easy for the reader.
First and last make it easy for the reader.

There is no real need for the usual wide space before the beginning of a new sentence. Compare the wide space that precedes the beginning of this sentence with the narrow space before the beginning of the next. This space is enough. The period and the capital letter in addition to the usual word-space mark clearly the beginning of a new sentence.

This is a good place to raise my voice against the common practice of "squaring up" one line with another line which does not contain the same number

Figure 52: Page 92 from Benjamin Sherbow's 1916 publication, Making Type Work, showing word spacing.
LINE SPACING

Why does your eye find this paragraph less inviting than those that follow? Isn’t it because those below look easier to read? They are. The lines you are now reading are set solid. There is no space between these lines except that provided by the shoulder of the type itself. And that is not enough for a type like this.

Between the lines of this paragraph a 3-point lead has been placed to give the relief of white that type needs to make it easy-to-read. There is no fixed rule about the proper amount of space to place between lines. It depends on the type face and the size you are using. Less leading for small types; more leading for large types. More leading for black-face types than for those of lighter face.

When you are using the same size of type throughout a booklet give it all uniform leading. Do not double-lead on one page to make the type come to a required depth. Nor take out all the leads on another page to make the type come within a given space. This is an unworkmanlike way of overcoming a difficulty. It looks slovenly and hurts the inviting-ness of your print. There is no good reason why type should fill a certain depth of the booklet page. No objection whatever to leaving part of a page blank. This white may give your booklet just the breathing space it needs. Read again on page 13 what I said about the selection of type for booklets.

On the other hand uneven spacing between lines is

Figure 53: Page 88 from Benjamin Sherbow’s 1916 publication, Making Type Work, showing the effect of different line spacing.
Appendix Three

Misread characters from existing research

Presented in Microsoft Excel file for sorting under different topics such as case, serif or sans serif and year.

Appendix Three contains an Microsoft Excel File containing published research by acknowledged authorities into misreading of type when conducting research into legibility and readability, such as Sanford (1888), Dockeray (1910), Tinker (1928), Bouma (1971) and for the lowercase Geyer (1977), Banister (1927), Tinker (1928), Fisher et al. (1969), Townsend condition 1 (1971), Loomis (1982), Phillips et al. (1983) and van der Heijden (1984)¹ (sourced from Sofie Beier’s 2012 publication, Reading Letters designing for legibility). As stated in Chapter 4 this file was used to sort the research on misreading of characters in Upper and lower case and serif and sans serif typefaces and by year to produce a comparative analysis. The research into misreading of these characters and a comparative analysis of same is the subject matter of chapter 4. The sort method is applied to existing research finding (section: Legibility of letters by comparing characters in the same typeface page 120 of chapter 3), each character is given a ranking 1 for the highest misread character in each piece of research.

<table>
<thead>
<tr>
<th>Upper/lower case</th>
<th>Researcher</th>
<th>Year</th>
<th>test method</th>
<th>Type face</th>
<th>Actual letter</th>
<th>Mistaken for</th>
<th>Frequency score (1 high, high number lower ranking)</th>
<th>Serif/sans serif</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>y</td>
<td>p</td>
<td>1</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>i</td>
<td>l</td>
<td>2</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>w</td>
<td>v</td>
<td>3</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>h</td>
<td>b</td>
<td>4</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>m</td>
<td>w</td>
<td>5</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>b</td>
<td>h</td>
<td>6</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>p</td>
<td>r</td>
<td>7</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>n</td>
<td>a</td>
<td>8</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>h</td>
<td>k</td>
<td>9</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>t</td>
<td>i</td>
<td>10</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>e</td>
<td>c</td>
<td>11</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>l</td>
<td>i</td>
<td>12</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>f</td>
<td>r</td>
<td>13</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>l</td>
<td>j</td>
<td>14</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>k</td>
<td>x</td>
<td>15</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>c</td>
<td>e</td>
<td>16</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>o</td>
<td>c</td>
<td>17</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>v</td>
<td>r</td>
<td>18</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>q</td>
<td>g</td>
<td>19</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>y</td>
<td>r</td>
<td>20</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>j</td>
<td>l</td>
<td>21</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>m</td>
<td>u</td>
<td>22</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Distance</td>
<td>Old style roman</td>
<td>c</td>
<td>o</td>
<td>23</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Distance</td>
<td>Courier</td>
<td>l</td>
<td>i</td>
<td>1</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Distance</td>
<td>Courier</td>
<td>g</td>
<td>q</td>
<td>2</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Distance</td>
<td>Courier</td>
<td>m</td>
<td>n</td>
<td>3</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Distance</td>
<td>Courier</td>
<td>w</td>
<td>v</td>
<td>4</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Distance</td>
<td>Courier</td>
<td>e</td>
<td>o</td>
<td>5</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Distance</td>
<td>Courier</td>
<td>i</td>
<td>l</td>
<td>6</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Distance</td>
<td>Courier</td>
<td>c</td>
<td>e</td>
<td>7</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Distance</td>
<td>Courier</td>
<td>h</td>
<td>b</td>
<td>8</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Distance</td>
<td>Courier</td>
<td>b</td>
<td>h</td>
<td>9</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Distance</td>
<td>Courier</td>
<td>r</td>
<td>f</td>
<td>10</td>
<td>Serif</td>
</tr>
<tr>
<td>Upper/lower case</td>
<td>Researcher</td>
<td>Year</td>
<td>test method</td>
<td>Type face</td>
<td>Actual letter</td>
<td>Mistaken for</td>
<td>Frequency score (1 high, high number lower ranking)</td>
<td>Serif/sans serif</td>
</tr>
<tr>
<td>------------------</td>
<td>------------</td>
<td>------</td>
<td>-------------</td>
<td>-----------</td>
<td>---------------</td>
<td>--------------</td>
<td>-----------------------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Lower</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>x</td>
<td>z</td>
<td>21</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>f</td>
<td>l</td>
<td>22</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>w</td>
<td>v</td>
<td>23</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>m</td>
<td>w</td>
<td>1</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>j</td>
<td>l</td>
<td>2</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>l</td>
<td>i</td>
<td>3</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>r</td>
<td>f</td>
<td>4</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>h</td>
<td>b</td>
<td>5</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>h</td>
<td>n</td>
<td>5</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>i</td>
<td>l</td>
<td>6</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>l</td>
<td>j</td>
<td>7</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>y</td>
<td>v</td>
<td>8</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>i</td>
<td>j</td>
<td>9</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>o</td>
<td>e</td>
<td>10</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>t</td>
<td>i</td>
<td>11</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>b</td>
<td>h</td>
<td>12</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>i</td>
<td>t</td>
<td>13</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>e</td>
<td>c</td>
<td>14</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>f</td>
<td>i</td>
<td>15</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>t</td>
<td>l</td>
<td>16</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>k</td>
<td>h</td>
<td>17</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>v</td>
<td>w</td>
<td>18</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>j</td>
<td>i</td>
<td>19</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>w</td>
<td>a</td>
<td>20</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>y</td>
<td>p</td>
<td>21</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Sanford</td>
<td>1888</td>
<td>Short exposure</td>
<td>Old style roman</td>
<td>z</td>
<td>x</td>
<td>22</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>e</td>
<td>o</td>
<td>1</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>f</td>
<td>i</td>
<td>2</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>b</td>
<td>h</td>
<td>3</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>e</td>
<td>a</td>
<td>4</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>i</td>
<td>l</td>
<td>5</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>c</td>
<td>r</td>
<td>6</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Upper/lower case</td>
<td>Researcher</td>
<td>Year</td>
<td>test method</td>
<td>Type face</td>
<td>Actual letter</td>
<td>Mistaken for</td>
<td>Frequency score (1 high, high number lower ranking)</td>
<td>Serif/sans serif</td>
</tr>
<tr>
<td>-----------------</td>
<td>------------</td>
<td>------</td>
<td>-------------</td>
<td>----------------</td>
<td>---------------</td>
<td>--------------</td>
<td>------------------------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>z</td>
<td>x</td>
<td>7</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>t</td>
<td>l</td>
<td>8</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>f</td>
<td>j</td>
<td>9</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>t</td>
<td>i</td>
<td>10</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>p</td>
<td>n</td>
<td>11</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>a</td>
<td>o</td>
<td>12</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>o</td>
<td>a</td>
<td>13</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>s</td>
<td>n</td>
<td>14</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>y</td>
<td>v</td>
<td>15</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>l</td>
<td>i</td>
<td>16</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>f</td>
<td>r</td>
<td>17</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>o</td>
<td>e</td>
<td>18</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>q</td>
<td>g</td>
<td>19</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>j</td>
<td>l</td>
<td>20</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>z</td>
<td>r</td>
<td>21</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>c</td>
<td>i</td>
<td>22</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Geyer</td>
<td>1977</td>
<td>Short exposure</td>
<td>Tactype Futura</td>
<td>l</td>
<td>j</td>
<td>23</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>l</td>
<td>i</td>
<td>1</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>s</td>
<td>a</td>
<td>2</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>g</td>
<td>q</td>
<td>3</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>c</td>
<td>e</td>
<td>4</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>b</td>
<td>h</td>
<td>5</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>n</td>
<td>m</td>
<td>6</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>z</td>
<td>a</td>
<td>7</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>e</td>
<td>a</td>
<td>8</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>c</td>
<td>o</td>
<td>9</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>k</td>
<td>h</td>
<td>10</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>s</td>
<td>e</td>
<td>11</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>z</td>
<td>e</td>
<td>12</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>h</td>
<td>b</td>
<td>13</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>k</td>
<td>b</td>
<td>14</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>x</td>
<td>a</td>
<td>15</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouma</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>r</td>
<td>f</td>
<td>16</td>
<td>Serif</td>
</tr>
<tr>
<td>Upper/lower case</td>
<td>Researcher</td>
<td>Year</td>
<td>test method</td>
<td>Type face</td>
<td>Actual letter</td>
<td>Mistaken for</td>
<td>Frequency score (1 high, high number lower ranking)</td>
<td>Serif/sans serif</td>
</tr>
<tr>
<td>------------------</td>
<td>------------</td>
<td>------</td>
<td>-------------------</td>
<td>------------</td>
<td>---------------</td>
<td>--------------</td>
<td>--------------------------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouna</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>r</td>
<td>t</td>
<td>17</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouna</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>z</td>
<td>r</td>
<td>18</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouna</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>o</td>
<td>e</td>
<td>19</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouna</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>u</td>
<td>n</td>
<td>20</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouna</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>t</td>
<td>i</td>
<td>21</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouna</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>i</td>
<td>l</td>
<td>22</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Bouna</td>
<td>1971</td>
<td>Short exposure</td>
<td>Courier</td>
<td>e</td>
<td>m</td>
<td>23</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>a</td>
<td>n</td>
<td>1</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>a</td>
<td>u</td>
<td>1</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>a</td>
<td>s</td>
<td>1</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>b</td>
<td>h</td>
<td>2</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>c</td>
<td>e</td>
<td>3</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>c</td>
<td>o</td>
<td>3</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>e</td>
<td>c</td>
<td>4</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>e</td>
<td>o</td>
<td>4</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>e</td>
<td>g</td>
<td>4</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>e</td>
<td>s</td>
<td>4</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>f</td>
<td>l</td>
<td>5</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>f</td>
<td>t</td>
<td>5</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>f</td>
<td>i</td>
<td>5</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>g</td>
<td>s</td>
<td>6</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>h</td>
<td>b</td>
<td>7</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>h</td>
<td>k</td>
<td>7</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>i</td>
<td>j</td>
<td>8</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>i</td>
<td>l</td>
<td>8</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>i</td>
<td>t</td>
<td>8</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>j</td>
<td>i</td>
<td>9</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>j</td>
<td>l</td>
<td>9</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>l</td>
<td>j</td>
<td>10</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>l</td>
<td>t</td>
<td>10</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>l</td>
<td>f</td>
<td>10</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>n</td>
<td>m</td>
<td>11</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>n</td>
<td>u</td>
<td>11</td>
<td>Serif</td>
</tr>
<tr>
<td>Upper/lower case</td>
<td>Researcher</td>
<td>Year</td>
<td>test method</td>
<td>Type face</td>
<td>Actual letter</td>
<td>Mistaken for</td>
<td>Frequency score (1 high, high number lower ranking)</td>
<td>Serif/sans serif</td>
</tr>
<tr>
<td>------------------</td>
<td>----------------</td>
<td>------</td>
<td>---------------------</td>
<td>---------------</td>
<td>---------------</td>
<td>-------------</td>
<td>-------------------------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>o</td>
<td>n</td>
<td>12</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>p</td>
<td>m</td>
<td>13</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>q</td>
<td>o</td>
<td>14</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>r</td>
<td>f</td>
<td>15</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>r</td>
<td>t</td>
<td>15</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>s</td>
<td>g</td>
<td>16</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>t</td>
<td>f</td>
<td>17</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>u</td>
<td>n</td>
<td>18</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>v</td>
<td>y</td>
<td>19</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>w</td>
<td>v</td>
<td>20</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>x</td>
<td>y</td>
<td>21</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>x</td>
<td>v</td>
<td>21</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>y</td>
<td>v</td>
<td>22</td>
<td>Serif</td>
</tr>
<tr>
<td>Lower</td>
<td>Dockerary</td>
<td>1910</td>
<td>Parafoveal vision</td>
<td>Old style roman</td>
<td>z</td>
<td>x</td>
<td>23</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>q</td>
<td>o</td>
<td>1</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>b</td>
<td>r</td>
<td>2</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>f</td>
<td>t</td>
<td>3</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>t</td>
<td>i</td>
<td>4</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>j</td>
<td>i</td>
<td>5</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>h</td>
<td>n</td>
<td>6</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>l</td>
<td>i</td>
<td>7</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>d</td>
<td>o</td>
<td>8</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>g</td>
<td>o</td>
<td>9</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>o</td>
<td>g</td>
<td>10</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>u</td>
<td>h</td>
<td>11</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>q</td>
<td>g</td>
<td>12</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>e</td>
<td>l</td>
<td>13</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>i</td>
<td>l</td>
<td>14</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>o</td>
<td>q</td>
<td>15</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>m</td>
<td>h</td>
<td>16</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>a</td>
<td>k</td>
<td>17</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>x</td>
<td>k</td>
<td>18</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>g</td>
<td>h</td>
<td>19</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Upper/lower case</td>
<td>Researcher</td>
<td>Year</td>
<td>test method</td>
<td>Type face</td>
<td>Actual letter</td>
<td>Mistaken for</td>
<td>Frequency score (1 high, high number lower ranking)</td>
<td>Serif/sans serif</td>
</tr>
<tr>
<td>------------------</td>
<td>-----------------------</td>
<td>------</td>
<td>---------------</td>
<td>-----------------</td>
<td>---------------</td>
<td>-------------</td>
<td>--------------------------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>r</td>
<td>h</td>
<td>20</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>p</td>
<td>f</td>
<td>21</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>f</td>
<td>i</td>
<td>22</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>i</td>
<td>t</td>
<td>23</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>v</td>
<td>y</td>
<td>24</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>w</td>
<td>h</td>
<td>25</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>i</td>
<td>j</td>
<td>26</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>g</td>
<td>c</td>
<td>27</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>b</td>
<td>n</td>
<td>28</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>m</td>
<td>n</td>
<td>29</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>b</td>
<td>n</td>
<td>30</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>m</td>
<td>n</td>
<td>31</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Townsend condition 1</td>
<td>1971</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>j</td>
<td>t</td>
<td>32</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>q</td>
<td>g</td>
<td>1</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>v</td>
<td>y</td>
<td>2</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>q</td>
<td>o</td>
<td>3</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>g</td>
<td>c</td>
<td>4</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>m</td>
<td>n</td>
<td>5</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>y</td>
<td>v</td>
<td>6</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>o</td>
<td>d</td>
<td>7</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>r</td>
<td>n</td>
<td>8</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>w</td>
<td>n</td>
<td>9</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>c</td>
<td>g</td>
<td>10</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>t</td>
<td>i</td>
<td>11</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>h</td>
<td>n</td>
<td>12</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>x</td>
<td>k</td>
<td>13</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>k</td>
<td>n</td>
<td>14</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>w</td>
<td>m</td>
<td>15</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>h</td>
<td>m</td>
<td>16</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>f</td>
<td>p</td>
<td>17</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>k</td>
<td>r</td>
<td>18</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>b</td>
<td>d</td>
<td>19</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>q</td>
<td>d</td>
<td>20</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Upper/lower case</td>
<td>Researcher</td>
<td>Year</td>
<td>test method</td>
<td>Type face</td>
<td>Actual letter</td>
<td>Mistaken for</td>
<td>Frequency score (1 high, high number lower ranking)</td>
<td>Serif/sans serif</td>
</tr>
<tr>
<td>------------------</td>
<td>-------------------</td>
<td>------</td>
<td>-------------</td>
<td>--------------------------</td>
<td>---------------</td>
<td>--------------</td>
<td>---------------------------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>x</td>
<td>n</td>
<td>21</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>c</td>
<td>o</td>
<td>22</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>d</td>
<td>o</td>
<td>23</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>k</td>
<td>l</td>
<td>24</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>b</td>
<td>n</td>
<td>25</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Banister table II</td>
<td>1927</td>
<td>Short exposure</td>
<td>Sans serif Green's type</td>
<td>d</td>
<td>g</td>
<td>26</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>p</td>
<td>f</td>
<td>27</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>q</td>
<td>o</td>
<td>1</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>r</td>
<td>b</td>
<td>5</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>c</td>
<td>g</td>
<td>6</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>x</td>
<td>n</td>
<td>7</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>n</td>
<td>s</td>
<td>8</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>k</td>
<td>r</td>
<td>9</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>r</td>
<td>b</td>
<td>10</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>y</td>
<td>v</td>
<td>12</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>l</td>
<td>i</td>
<td>14</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>o</td>
<td>q</td>
<td>15</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>t</td>
<td>i</td>
<td>16</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>y</td>
<td>x</td>
<td>17</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>e</td>
<td>f</td>
<td>18</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>e</td>
<td>l</td>
<td>19</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>u</td>
<td>i</td>
<td>20</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>u</td>
<td>l</td>
<td>21</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>g</td>
<td>c</td>
<td>22</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>g</td>
<td>o</td>
<td>23</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>f</td>
<td>i</td>
<td>24</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>h</td>
<td>u</td>
<td>25</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>h</td>
<td>r</td>
<td>26</td>
<td>Serif</td>
</tr>
<tr>
<td>Upper/lower case</td>
<td>Researcher</td>
<td>Year</td>
<td>test method</td>
<td>Type face</td>
<td>Actual letter</td>
<td>Mistaken for</td>
<td>Frequency score (1 high, high number lower ranking)</td>
<td>Serif/sans serif</td>
</tr>
<tr>
<td>------------------</td>
<td>------------</td>
<td>------</td>
<td>-------------</td>
<td>-----------</td>
<td>---------------</td>
<td>--------------</td>
<td>------------------------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>j</td>
<td>i</td>
<td>27</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>t</td>
<td>y</td>
<td>28</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>c</td>
<td>l</td>
<td>29</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>b</td>
<td>r</td>
<td>30</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>t</td>
<td>f</td>
<td>31</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Tinker</td>
<td>1928</td>
<td>Short exposure</td>
<td>Low contrast Didone style</td>
<td>w</td>
<td>m</td>
<td>32</td>
<td>Serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>q</td>
<td>o</td>
<td>1</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>m</td>
<td>u</td>
<td>2</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>o</td>
<td>g</td>
<td>3</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>h</td>
<td>n</td>
<td>4</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>y</td>
<td>v</td>
<td>5</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>p</td>
<td>f</td>
<td>6</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>f</td>
<td>p</td>
<td>7</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>v</td>
<td>y</td>
<td>8</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>g</td>
<td>o</td>
<td>9</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>b</td>
<td>d</td>
<td>10</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>c</td>
<td>g</td>
<td>11</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>m</td>
<td>w</td>
<td>12</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>e</td>
<td>c</td>
<td>13</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>d</td>
<td>o</td>
<td>14</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>y</td>
<td>f</td>
<td>15</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>y</td>
<td>t</td>
<td>16</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>g</td>
<td>q</td>
<td>17</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>o</td>
<td>q</td>
<td>18</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>r</td>
<td>n</td>
<td>19</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>m</td>
<td>h</td>
<td>20</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>b</td>
<td>s</td>
<td>21</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>w</td>
<td>m</td>
<td>22</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>s</td>
<td>b</td>
<td>23</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>r</td>
<td>h</td>
<td>24</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>x</td>
<td>k</td>
<td>25</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>z</td>
<td>j</td>
<td>26</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Upper/lower case</td>
<td>Researcher</td>
<td>Year</td>
<td>test method</td>
<td>Type face</td>
<td>Actual letter</td>
<td>Mistaken for</td>
<td>Frequency score (1 high, high number lower ranking)</td>
<td>Serif/sans serif</td>
</tr>
<tr>
<td>------------------</td>
<td>----------------</td>
<td>------</td>
<td>---------------------</td>
<td>----------------------------</td>
<td>---------------</td>
<td>--------------</td>
<td>---------------------------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>k</td>
<td>x</td>
<td>28</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>h</td>
<td>m</td>
<td>29</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>b</td>
<td>r</td>
<td>30</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>s</td>
<td>f</td>
<td>31</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Loomis</td>
<td>1982</td>
<td>Blurring by diffusion</td>
<td>Helvetica Extra Light</td>
<td>q</td>
<td>c</td>
<td>32</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>y</td>
<td>t</td>
<td>1</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>m</td>
<td>w</td>
<td>2</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>f</td>
<td>t</td>
<td>3</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>h</td>
<td>m</td>
<td>4</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>r</td>
<td>a</td>
<td>5</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>b</td>
<td>p</td>
<td>6</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>k</td>
<td>x</td>
<td>7</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>w</td>
<td>m</td>
<td>8</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>g</td>
<td>q</td>
<td>9</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>v</td>
<td></td>
<td>10</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>e</td>
<td>c</td>
<td>11</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>b</td>
<td>r</td>
<td>12</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>h</td>
<td>w</td>
<td>13</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>h</td>
<td>n</td>
<td>14</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>q</td>
<td>o</td>
<td>15</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>z</td>
<td>j</td>
<td>16</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>x</td>
<td>a</td>
<td>17</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>k</td>
<td>a</td>
<td>18</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>q</td>
<td>g</td>
<td>19</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>d</td>
<td>p</td>
<td>20</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>o</td>
<td>d</td>
<td>21</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>p</td>
<td>f</td>
<td>22</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>t</td>
<td>i</td>
<td>23</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>z</td>
<td>i</td>
<td>24</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>e</td>
<td>j</td>
<td>25</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>e</td>
<td>k</td>
<td>26</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>x</td>
<td>k</td>
<td>27</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>n</td>
<td>m</td>
<td>28</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Upper/lower case</td>
<td>Researcher</td>
<td>Year</td>
<td>test method</td>
<td>Type face</td>
<td>Actual letter</td>
<td>Mistaken for</td>
<td>Frequency score (1 high, high number lower ranking)</td>
<td>Serif/sans serif</td>
</tr>
<tr>
<td>------------------</td>
<td>------------</td>
<td>------</td>
<td>--------------</td>
<td>-----------</td>
<td>--------------</td>
<td>-------------</td>
<td>------------------------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>o</td>
<td>m</td>
<td>29</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>g</td>
<td>n</td>
<td>30</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>d</td>
<td>r</td>
<td>31</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Phillips et al.</td>
<td>1983</td>
<td>Distance</td>
<td>Helvetica</td>
<td>k</td>
<td>r</td>
<td>32</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>q</td>
<td>o</td>
<td>1</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>x</td>
<td>y</td>
<td>2</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>s</td>
<td>g</td>
<td>3</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>f</td>
<td>p</td>
<td>4</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>e</td>
<td>f</td>
<td>5</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>q</td>
<td>g</td>
<td>6</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>v</td>
<td>y</td>
<td>7</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>k</td>
<td>x</td>
<td>8</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>t</td>
<td>i</td>
<td>9</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>o</td>
<td>q</td>
<td>10</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>w</td>
<td>k</td>
<td>11</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>o</td>
<td>g</td>
<td>12</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>m</td>
<td>h</td>
<td>13</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>b</td>
<td>g</td>
<td>14</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>l</td>
<td>i</td>
<td>15</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>r</td>
<td>p</td>
<td>16</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>w</td>
<td>r</td>
<td>17</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>n</td>
<td>k</td>
<td>18</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>w</td>
<td>x</td>
<td>19</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>o</td>
<td>c</td>
<td>20</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>o</td>
<td>d</td>
<td>21</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>i</td>
<td>t</td>
<td>22</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>b</td>
<td>r</td>
<td>23</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>w</td>
<td>m</td>
<td>24</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>p</td>
<td>r</td>
<td>25</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>b</td>
<td>s</td>
<td>26</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>x</td>
<td>k</td>
<td>27</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>p</td>
<td>f</td>
<td>28</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>q</td>
<td>d</td>
<td>29</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Upper/lower case</td>
<td>Researcher</td>
<td>Year</td>
<td>test method</td>
<td>Type face</td>
<td>Actual letter</td>
<td>Mistaken for</td>
<td>Frequency score (1 high, high number lower ranking)</td>
<td>Serif/sans serif</td>
</tr>
<tr>
<td>------------------</td>
<td>------------------</td>
<td>------</td>
<td>-----------------</td>
<td>-------------------</td>
<td>---------------</td>
<td>--------------</td>
<td>-----------------------------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>w</td>
<td>n</td>
<td>30</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>u</td>
<td>w</td>
<td>31</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>van der Heijden</td>
<td>1984</td>
<td>Short exposure</td>
<td>Sans serif</td>
<td>i</td>
<td>j</td>
<td>32</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>t</td>
<td>i</td>
<td>1</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>q</td>
<td>o</td>
<td>2</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>j</td>
<td>i</td>
<td>3</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>x</td>
<td>k</td>
<td>4</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>f</td>
<td>i</td>
<td>5</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>d</td>
<td>o</td>
<td>6</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>l</td>
<td>i</td>
<td>7</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>v</td>
<td>y</td>
<td>8</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>k</td>
<td>n</td>
<td>9</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>c</td>
<td>o</td>
<td>10</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>f</td>
<td>p</td>
<td>11</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>i</td>
<td>t</td>
<td>12</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>s</td>
<td>b</td>
<td>13</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>f</td>
<td>t</td>
<td>14</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>g</td>
<td>o</td>
<td>15</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>r</td>
<td>k</td>
<td>16</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>u</td>
<td>o</td>
<td>17</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>p</td>
<td>i</td>
<td>18</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>c</td>
<td>g</td>
<td>19</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>e</td>
<td>i</td>
<td>20</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>e</td>
<td>l</td>
<td>21</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>h</td>
<td>n</td>
<td>22</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>i</td>
<td>j</td>
<td>23</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>k</td>
<td>r</td>
<td>24</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>l</td>
<td>t</td>
<td>25</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>e</td>
<td>f</td>
<td>26</td>
<td>Sans serif</td>
</tr>
<tr>
<td>Higher</td>
<td>Fisher et al.</td>
<td>1969</td>
<td>Short exposure</td>
<td>Futura medium</td>
<td>q</td>
<td>g</td>
<td>27</td>
<td>Sans serif</td>
</tr>
</tbody>
</table>