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Principles of typography for the screen

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Principles of Typography for the Screen

By

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List of Terms

ascender height: The distance between the mean line to the ascender line.

base line: The line on which a character rests.

bloat: The expanding or swelling of a file or file system due to the increase of information being stored.

browser: A computer software program that allows computer users to view web pages and documents that utilize the Hyper Text Mark-up Language.

descender length: Refers to the distance between the baseline to the descender line.

em space: An em space is a unit of measurement that is the square of the point size. It is also known as the em quad.

font fidelity: The ability to reproduce and distribute electronically an accurate font rendering.

interlacing: The way a computer screen re-draws an image by alternating the illumination of odd and even lines across a screen.

jaggies: A term used to describe the rough edges of characters at low resolutions. Also known as aliasing.

justification: Paragraph formatting which can be described as flush left, flush right, i.e. even on both ends of the lines with the possible exception of the last line of the paragraph.

leading: The added space between lines of type.

legibility: The ability to perceive letters and words when reading continuous text. To perceive these words with speed, accuracy and with comprehension.

mean line: The line defining the top of the lower case letters that are without ascenders.

pica: A unit of measurement used in typography and typesetting. There are 6 picas in an inch.

points: A unit measurement system used to measure type sizes and leading. There are 12 points in a pica and 72 points in an inch.

readability: A term related to legibility. Readability is based on speed of reading whereas legibility is based on the shape of each character.

resolution: Refers to the number of dots or pixels required to render an image. Dots per inch (dpi) is the unit used to describe the resolution of printed material. Pixels per inch (ppi) refers the number of pixels that are needed to render an image on a computer monitor.

serifs: A small stroke at the end of a main stroke on a letterform.

solid: No extra space between the lines of type.

tachistoscope: An apparatus for use in exposing visual stimuli, as letters or words for an extremely brief moment, usually a tenth of a second.

typography: The art and practice of designing type, books, magazines and other printed matter.

word space: The white space separating words in a line of text.

x-height: The distance between the baseline and the mean line. The height of a lowercase letter that has no ascender or descender such as the lowercase x.

Abstract

For the past 500 years humans have been developing means of communication through the development of technology for producing and presenting pages of printed text to the reader. The idea of communicating with letters by the composition of a page grew from traditional manuscript writing of the 15th century to today's electronic portable document for the World Wide Web. But unlike the properties of ink on paper, computers, monitors and electronic documents pose many new and different problems which don't apply to paper.

One of the major problems with viewing text on a monitor is resolution. Most monitors today have 72 dots per inch—considerably less than the 2400 dots per inch used for print. The second problem associated with on-screen reading is the uncomfortable viewing conditions caused by flicker on a computer monitor. Due to these deficiencies, good font rendering on computer screens is nearly impossible.

The purpose of this study was to develop a new set of typographic parameters to compensate for on-screen reading and viewing. By evaluating legibility studies for print and various studies for the legibility of computer monitors, conclusions can be made about how text should be set and arranged for the screen.

In this study nine tests were designed to find the preferred characteristics of typography for the screen. The nine factors tested were: typeface, type size, leading, line length, paragraph indent, text format, hyphenation, margins and color. Each

characteristic chosen for testing was based upon the viewing conditions of todays computer screens. Three-hundred and eight electronic documents were created and linked together for two testing sessions. The observers were shown various paragraphs of text and were asked to choose which paragraph was more legible to them. The preferences for each observer were marked on each final test page so that the results could be calculated.

Based on the results of the testing for this experiment, using the paired comparison method, the hypothesis has been proven to be correct. Out of nine separate tests, seven principles must be changed to ensure legibility for on-screen reading. By further analysis of the results of the testing, the author found that there were no significant differences between what was preferred by male versus female observers.

Chapter 1

Statement of the Problem

There is no doubt that the printed page will never disappear. There is a subconscious comfort in holding a book in our hands and evaluating its details not to mention its portability (which differs greatly from the portability of the electronic document). But in the same respect, the electronic documents' innumerable benefits will enhance its growth as well as its use. Although both mediums are useful to us, we tend to use what makes us more comfortable and after a decade of reading type on the screen we are not very pleased with what we see.

One of the first problems we face are the visual properties of computer monitors. An image is rendered by a computer using a Cathode Ray Tube (CRT). A color CRT has three electron guns that generate three beams of electrons. These electron beams charge the phosphor grid which is found behind the screen of the monitor. The phosphor grid is illuminated by these electron beams. The intensity and locations of each spot or pixel is controlled by deflecting plates which are used to bend the beams of light. These deflecting plates distribute the electron beams so the beam can trace an image on the screen.[1] The speed of the beam directly affects the refresh rate or redraw time of the monitor. On some monitors, the screen redraw occurs when two alternating lines are scanned on the screen. This scanning process is known as *interlacing*. The interlacing process scans odd number lines and then forms the even lines on the screen. Slower redraw times on

monitors can cause *flicker*—the illusion that each pixel is blinking. The faster the redraw speed the less flicker the human eye will detect. Average consumer monitors have variations of noticeable flicker which creates an uncomfortable viewing condition.

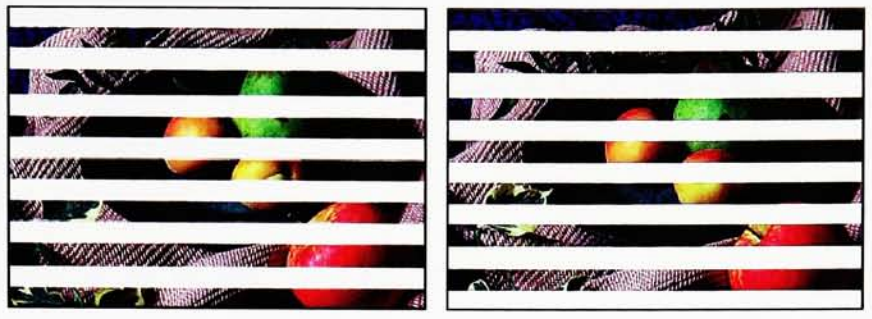

Figure 1. Odd and even interlacing.

Another problem with computer monitors which affects viewing text is resolution. The phosphor grid inside the monitor is made up of cells known as pixels. The term pixel can be defined as the smallest addressable area on a screen. The resolution of a monitor ranges from 72 to 120 dots per inch. This low resolution contributes to problems with rendering type on the screen. Usually there is not enough pixels present on a monitor to represent the detail we would like to see. At the low end of the scale, there may only be 5 or 6 pixels available (vertically) to draw a 12 point lowercase letter on the screen (compared to 95 pixels on an imagesetter).[2] Furthermore, the average computer monitor ranges from 13 inches to 15 inches with a base number of 640 x 480 pixels usually in a horizontal direction. This low

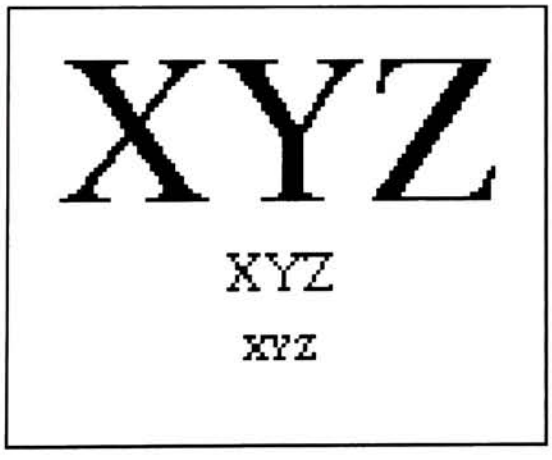

Figure 2. Fonts on the screen.

resolution contributes to the discomfort of viewing type on the screen because our eyes cannot see detail. Monitors cannot render smooth lines, letters like X, Y and Z will have "jaggies."(see Figure 2)

Due to the properties of the monitor in the relation to comfort and the lack of good font rendering on the screen, we find it hard to pay attention when reading most electronic documents. It is obvious that the properties of the screen are very different than the properties of print on paper. First of all, the resolution of most laser printers range from 300 to 600 dot per inch, 4 to 8 times the resolution of the average monitor. On paper, we have complete control over what the end user will actually see on a printed page. On the screen, we have no control. Furthermore, after decades of empirical and clinical research, typography for the printed page has been established in terms of legibility and readability. Typography for the screen has not. This study will concentrate on finding better ways to typographically position type and attempt to establish some typographical principles that can be applied to the screen so that it is more comfortable for the human eye—therefore, providing legibility. This study will take into account all aspects of the end user so that the characteristics of typography produce a page that any reader can view correctly, comfortably and easily.

End Notes for Chapter 1

1 David Macaulay, *The Way Things Work* (Boston, Massachusetts: Houghton Mcfflin Company, 1988), 262.

2 Kathleen Tinkel, "Anti-Aliasing Evolves," *Adobe Magazine* 8, 3 (January, 1997): 34.

Chapter 2

Background, Significance and Review of Literature

When the scribes of medieval times produced books they were considered works of art. They attempted to please God through beautiful hand lettering and elaborate decorative type. The content of books was not about communication. With the invention of moveable type and the mass production of books, the purpose of the book soon changed. As the number of Universities and Churches grew, the levels of education rose dramatically causing a need for more books. By the twentieth century, the literacy rate climbed and the amount of information that could be transmitted by books increased. Factors such as reading and comprehension became important issues as more printed messages were being distributed. And as the need for effective communication became more apparent, "typography emerged as a functional aspect of print communication."[1]

The scientific investigation of typographic legibility began the development of new, "functional typography." The way people perceived type in different arrangements and forms was studied to provide maximum legibility. These investigations were concerned with increasing reading speed and comprehension and identifying the appropriate kinds of typographical arrangements that contributed.[2] Research on legibility of typography could only be established if there was a clear definition of the term legibility. Legibility means different things

to different people. For the purpose of this thesis, legibility as defined by Miles Tinker, will be used:

> "Legibility, (then), is concerned with perceiving letters and words, and with the reading of continuous textual material. The shapes of letters must be discriminated, the characteristic word forms perceived, and continuous text read accurately, rapidly, easily, and with understanding. In the final analysis, one wants to know what typographic factors foster ease and speed of reading."[3]

Before introducing the research findings of legibility studies, it is important to understand how our eyes perceive printed words. As our eye follows a line of text it has been found that our eyes move with a series of leaps, with moments of rest or "fixation." At this moment of rest actual perception of words takes place and the eye moves onward. During these saccadic eye movements the muscles of the eye must adjust continuously. Our eyes are naturally adjusted to focus on objects five feet or more distant, and anything closer can cause a fatiguing adjustment. Blinking has been found as an act of rest for eyes that experience this fatigue. Any unusual or distracting features in near vision tend to increase periods of fixation and interrupts the rhythmic movement of the eye, which will induce fatigue.[4] On occasion the eye might move backward on a line of text in order to re-read what was not comprehended the first time around. These backward eye movements are called "regressions." Pause or perception time when reading text usually involves ninety-two to ninety-four percent of reading time.[5] The measurement of eye movements have provided great information on how typographic arrangements are perceived.

The typographical elements of a printed page in relation to legibility have been narrowed down to seven typographic variables (some are based on a list created by the Swedish legibility expert Bror Zachrisson); (1) typeface: seven categories; (2) emphasis; (3) line length and paragraph indention; (4) amount of leading; (5) color and contrast; (6) format arrangement; (7) page size, margins and columns.[6]

1.) Typefaces

During the pioneer stages of legibility research, the importance of character shape and space was discovered. For example, Berger found that the width of an individual letter contributed to legibility. He found that condensed typeface designs are more difficult to read than extended typeface design.[7] Another important factor of the legibility of a typeface is white space. Recognition of letters is influenced not only by the space around the characters but also by the white space within letters—such as an o, e, a . . . .[8] Before getting into characteristics of the legibility of typefaces, it is important to understand the seven different categories of typeface design:

Figure 3. Categories of typeface design.

Inscriptional typefaces are all capital letters and have light to medium weight. They are said to be derived from roman letterforms that were carved in stone. A characteristic of a true inscriptional is that they have narrow E's, F's and L's. Typefaces such as Trajan and Castellar are considered inscriptionals.

Figure 4. Samples of Inscriptionals.

Blackletter typefaces originated in Northern Europe. Although originally used as the normal writing script, nowadays they are often reserved for newspaper titles and seasonal material.

Uncial letters were widely used by European scribes from the 4th to 9th century AD. They vanished from common use very early on, but were a source for our "roman types." Uncials usually have one case, and are used well as a display face.

Scripts and *Cursives* are separated into two categories: *formal* and *informal.* Both categories possess a hand written appearance. The difference between Script and Cursive is that the Script characters are connected and the Cursives are not. There are many variations of script typefaces but usually the more fancy a script the less legible it becomes.

Serifs, although there are many subcategories, can be broken down into two common categories: *Old* style and *Modern*. Figure 5 shows the differences in shape. Generally, an Old style design has diagonal stress in the serifs. There is little gradual transition from thick to thin strokes and the serifs are bracketed. The Modern face has vertical stress and extreme contrast between thick and thin.[9]

Figure 5. Categories of Serif type.

The serif typeface has been found to be the most legible of all of the categories because of its variable shapes and contrast.

Sans Serif typefaces can be grouped into two basic categories: stress variation and monotone. There is a lack of a serif and little or no difference in thickness between strokes. Stress variation, as the name implies, has contrast between thick and thin strokes of the characters. Monotone typefaces have no stress variation.

Figure 6. Categories of San Serif type.

Ornamental faces are normally not used in continuous text matter. They have been created for display arrangements. The proper use of such faces is to the discretion of the typographer or designer.

The designs of individual letters is crucial when trying to establish legibility. Tinker states that variables influencing legibility of individual letters are the complexity of letter outline, stroke width, heaviness, weight of hairlines, space within and around the letter, and differentiating letter features.[10] In an investigation of the legibility of typefaces, Miles Tinker and Donald Paterson recorded eye measurements of subjects reading material using two extremely different type designs; Cloister (Blackletter) and Scotch Roman (Serif Modern Face). This test determined the differences in eye movements and found that there was a thirteen percent retardation in speed of reading Cloister Black. When Tinker and Paterson tested ten typefaces in 1963. Cloister was placed in tenth place.[11]

Ten Typefaces Ranked According to Reader Opinions of Relative Legibility

Typeface	Category	Rank
Cheltenham	S	1
Antique	S	2
Bodoni	S	3
Old Style	S	4
Garamond	S	5
American Typewriter	S	6
Scotch Roman	S	7
Caslon Old Style	S	8
Kabel Light	SS	9
Cloister Black	BL	10

S= serif
SS= sans serif
BL= blackletter

Table 1. Legibility test by Tinker and Paterson.[12]

Another test for legibility of a typeface was performed by masking a portion of the text to see which characters could still be recognized. By masking off part of a letter you can get better cues of how easily it can be recognized. Researchers have found that masking the bottom half of a lowercase letter is the most significant technique for testing letter recognition.[13] From this test we see that Serif typefaces provide more clues than the Sans Serif.

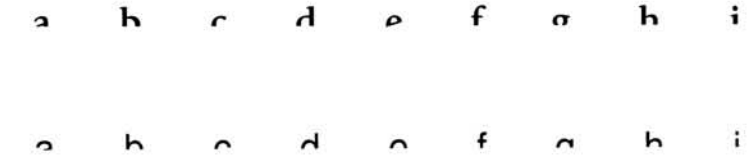

Figure 7. Masking test for legibility.

Many other tests on legibility of a typeface have been done using comprehension as a testing measure. Richard Pyke, from the Medical Research Council in Great Britain, used speed-of-reading experiments with different typefaces to measure which was more legible. Gerrit Ovink's experiments found differences in the legibility of old style serifs and monotone sans serifs. His tests involved presenting text for one second and asking the subject the last word he saw. Although Ovink only found slight differences, serif types were more legible. In 1964, a legibility study concluded that roman serif faces were far superior to san serifs. A page set in roman took thirty-eight seconds to read while the same page set in a sans serif took forty-one seconds. Most tests using reading comprehension have proved that serif typefaces are more legible than sans serif.

Although the scientific studies of the legibility of typeface design have proven successful, there is another factor which must be mentioned. When the eye struggles to see shapes, the subjects of these tests are assigned to the complex task of ingesting meanings from word images. Is it reassuring that a type look familiar? The psychological effects of type can hinder comprehension, like, not being familiar with a particular typeface. Psychological studies have found a correlation between aesthetic preference to ease-of-reading. A group of readers with a background in scientific education will tend to prefer a modern face while another group with 'literary', non-scientific background can think of fourteen other designs that they would like better. Thus, it is safe to say that legibility can be effected by what typeface the reader is used to.[14]

Too sum up recommendations about type face styles and their relationship to legibility, here are a few guidelines. Extensive legibility studies have shown that :

1. Blackletter typefaces retard the speed of reading, therefore, should not be used in continuous texts.
2. The most legible typefaces are serifs due to their contrasting shapes.
3. Perhaps the most important issue regarding legibility is that the ease at which we read can depend on what type styles we are accustomed to.

2.) Emphasis

To create emphasis on a printed page is to add contrast to the text so that words stand out or words contrast other words. Emphasizing type can take many forms including boldness versus light or "normal," upright versus slanted and capitals versus lower case. Many tests on legibility have found that emphasizing all the

type in continuous text—like a group of text set up in all caps—is not as legible as continuous text set in plain lowercase roman. Nevertheless, emphasis is an important functional aspect of typography when used appropriately.

bold normal
upright *slanted*
CAPITALS lowercase

Figure 8. Emphasis.

Figure 8 shows the three general categories for emphasizing type. The benefit of emphasizing type with boldness is that bold faces can be perceived at greater distances than plain roman. The slanted posture of italic type can emphasize type without sacrificing legibility. The most problematic aspect of emphasizing type can be found when using all capitals. Several tests have shown that material set in all capital letters read twelve percent slower than all lower case letters. It is recommended not to used all caps in continuous texts because they lack shape and visibility as shown in Figure 9.

Figure 9. Shape.

3.) Line Length and Paragraph Indention

The rules of line length and paragraph indention, although they are not independent factors, contribute to the legibility of text. Numerous legibility tests have been conducted which have found that a maximum legible line length cannot be determined unless type size, leading and typeface are considered.[15] In

most of the legibility studies documented today, it is apparently clear that the human eye indicates what line length is most legible. As our eyes follow a line of text across a page, the ends and the center of a line are at different distances from our eyes and this difference increases with longer line lengths. To accommodate, our eyes must continually change focus which can be more harmful and fatiguing than small character to character jumps used when viewing smaller line lengths. Perception of very wide lines can be difficult and inaccurate when trying to relocate to the beginning of a new line. Both empirical and non-empirical tests have shown that people prefer a moderate line length and that the maximum line length should not exceed four inches.[16] A good rule of thumb for line length—established by studies of legibility—is that line length should not exceed sixty characters and the minimum is nine words per line. Table 2 shows the "safety zones"—partly established by Tinker—for good line length based on point size.

Line Lengths (LL)

Point Size	LL
6	9-28
8	13-25
10	14-31
12-14	17-33

Table 2. Point size to line length.[17]

The purpose of a paragraph indent is to mark a pause or set a paragraph apart from what precedes it. Paragraph indention's are directly related to line length. It has been found that large paragraph indention's can grow tiresome in long texts.[18] In a study of spatial arrangements of a printed page, Tinker found that paragraph indention increased legibility by seven percent.[19]

There are many ways to mark a paragraph indention such as adding a pilcrow or an ornament, but the most common way of identifying a new paragraph is by adding white space. A set of standard values for paragraph indention's—which is applied to the first line of a new paragraph, unless it is a new paragraph at the top of the page—should be used for the most legible text. They are shown below:

Paragraph Indents

LL	Indent
9-18	1 em
19-23	1 1/2 em
24-33	2 em

Table 3. Paragraph indents.

A general rule for paragraph indention is that as line length and point size increase proportionally the indent must also increase.

4.) Amount of Leading

The correct amount of leading for legibility has been extensively studied by legibility experts like Becker, Bently, Zachrisson, Tinker and Paterson. They have all found that the typeface involved in the text influences the amount of leading. They have found that text with no leading added (known as "solid") is read considerably slower than text with added lead. For optimal text sizes (nine to twelve points) the best leading ranges from one to four points added lead depending on the typeface. A general rule about leading is that the amount of leading depends on the x-height of a character, the height of the ascenders and

The typeface Times has a large x-height. Times would require more leading because the x-height in proportion to the ascenders and descenders is larger. A general rule about type is that when the x-height is large more leading is needed to compensate for less white space. This type is 10/10 pts.

The typeface Bodoni has a small x-height. Its ascenders and descenders are long but they do not touch when set solid. Bodoni would require more lead because vertical stress fills in white space necessary for legibility. This type 10/10pts.

The typeface Garamond has a small x-height. Its ascenders and descenders are long but the small x-height creates more white space. The smaller the x-height the longer the descenders, so, more leading is needed. This type 10/10pts.

The typeface Helvetica has a larger x-height. Its ascenders and descenders are short. Helvetica would require more leading because more white space is needed for legibility. This type is 10/10 pts.

Figure 10. Solid Leading and X-height.

the height of the descenders. Figure 10 shows how four typefaces differ in x-height. The result of Figure 10 is that it appears that typefaces with smaller x-heights have more lead. Each typeface needs to be treated differently depending on the characteristics of that typeface. Therefore, it is safe to say that the optimal leading depends on the typeface but adding one to four points leading is used for maximum legibility. The weight of a typeface is also a factor. Generally, bolder typefaces need more leading than lighter typefaces.[20] A good rule to follow is that you should add twenty percent of the point size to the leading for optimal legibility of text sizes—type sizes between 8 and 14 points.

5.) Color and Contrast

The relationship between color of print and contrast has a great impact on the legibility of type. The most significant range of color/contrast can be seen in black and white. The most attention-getting combination is when white text is used on a black background—often used in advertising. Although white type on a black

background has a greater impact it is not as legible as black type on a white background. A study done by Tinker showed that seventy-seven percent of 244 readers rated that black text on a white background was more legible.[21] An eye movement study by Taylor reported that fixation frequency and perception time were significantly greater for reading white type on a black background. It was later found that the perception of black on white was more successful even at a distance. A variety of tests were conducted to test perceptability at a distance. Taylor found that even when changing the type size and typeface, real and nonsense words were clearly seen in black text rather than white.[22]

Another related problem with contrast can be seen when placing black type over a tinted or colored substrate. When printing black on color a bright contrast between the two must be apparent for the type to be legible. Therefore, printing black with the lightest background will enable better legibility. Tinker worked on two studies on color combinations and concluded that the most efficient combinations for black is; black and white and; black and yellow.[23]

Figure 11. Color combinations for black type.

Experiments of ink and paper combinations have also shown that the more the colors contrast each other the more legible type becomes. The color combinations in Figure 12 were tested by Tinker and Paterson in 1931. They tested 850 college students on the speed of reading material—using black and white as a standard. Table 4 shows how the color combinations ranked according to 210 reader opinions of relative legibility.

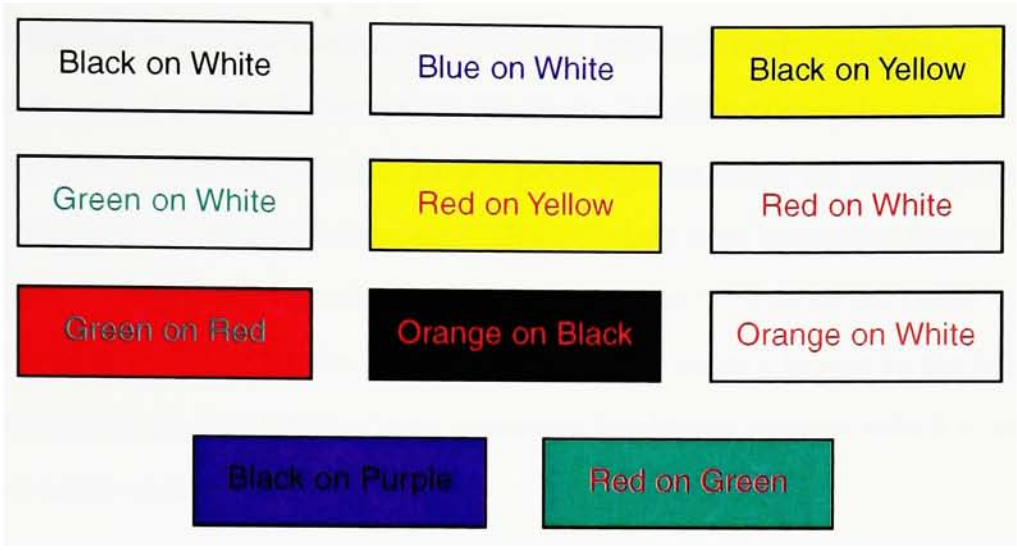

Figure 12. Colors combinations.[24]

Color Combinations Ranked by the Most Legible.

Color Combinations	Average Rank	Rank
Black on White	2.1	1
Blue on White	2.8	2
Black on Yellow	2.9	3
Green on White	4.2	4
Red on Yellow	5.3	5
Red on White	5.4	6
Green on Red	5.7	7
Orange on Black	7.6	8
Orange on White	9.1	9
Black on Purple	10.2	10
Red on Green	10.5	11

Table 4. Colors combination table.[25]

Black on white had the fastest reading time in every comparison. Green on white, blue on white and black on yellow were almost as effective as black on white. All of the other combinations are discouraged from being used whenever reading is a

factor. The last four color combinations induce very unfavorable reading conditions and it is inadvisable ever to use them. "Legibility depends not upon the color of the print and of paper surface primarily, but rather on the brightness contrast between print and background. This principle is so important that we are justified in calling it 'the law of brightness and contrast.'" [26] Out of the color combinations in Figure 12, the maximum brightness contrast is seen in the first four combinations. The last five have minimum brightness contrast which is why they are unfavorable.

6.) Format Arrangement

The format arrangement of a printed page can be affected by type sizes and paragraph arrangements. These two elements are proportional. That is, the appropriate type size and paragraph arrangement must be coordinated in order to be legible. Research studies on the appropriate sizes of type have concluded some rules about appropriate sizes for display type versus text which are shown in Figure 13.

Type Sizes	
Text	8-14 pts
Display	15+ pts

Table 5. Type sizes.

Tinker and Paterson found that nine to twelve point type enabled maximum legibility for text. Type sizes which were larger increased the number of fixations since they take up more space. Larger text sizes forced readers to perceive words in sections rather that in paragraphs. They also found that people prefer moderate type sizes and small amounts of leading.[27]

The arrangement of a paragraph includes all the attributes that make a paragraph legible including point size, line length, leading, format and hyphenation. A combination of these factors must be considered for legibility. The importance of point size is that it affects all the other attributes of legibility—like line length and leading which were explained earlier. Text format and hyphenation can also affect legibility. First of all, when formatting text, type can be set as flush left (ragged right), flush right (ragged left), justified or centered. Figure 13 shows examples of these arrangements.

Flush Left
This text is flush left which is also known as ragged right. It is the most popular formats used today because of its legibility.

Flush Right
This text is flush right which is also known as ragged left. It is not as popular as flush left. It has been found that flush right is not the optimal format.

Justified
Justification is when both right and left sides of the text is equal. It is a common format for books and for newspapers. The last sentence of a paragraph is usually set flush left.

Centered
This text is centered. This is not the optimal format for continuous text matter. It is often used in headlines and in advertisements.

Figure 13. Justification.

Which text format is optimal for legibility? If a paragraph of text is set Flush Left, word space will be fixed and unchanging. In Justified text, word space must be elastic. That is, it will change depending on point size and line length (and hyphenation).[28] Since the human eye is sensitive to white space and negative space—shown in Figure 14—justifying type can be tricky. If justification isn't applied correctly legibility will suffer. Researchers have found that there is generally no significant difference in legibility between justified and flush left text if it is set properly.

white space negative space

Figure 14. White Space and Negative Space.

The conventional methods of justification just described have been challenged by legibility researchers and other methods of justification have been proposed. In 1955, Kujus, proposed a form of boustrophedonic arrangement. Using this arrangement the eye would perceive words from left to right and continue to the next line from right to left. Kujus' modified version of the boustrophedonic style allows each word to read from left to right but the lines of type would alternate. Figure 15 illustrates this arrangement. Kujus found that this format would reduce eye movement strain by twenty-five percent.[29]

Reading type from left to right
left to right from then and
although, the words would
to left from reading remain
right.

Figure 15. Boustrophedonic arrangement.

Another challenge to conventional typographic format was introduced by Themerson, who believed that comprehension could be enabled by using internal vertical justification (IVJ). This arrangement of text used varying indents and line lengths to create shorter eye movements for greater legibility. IVJ is shown in Figure 16.

The theory behind Internal Vertical Justification
is that by adding various
indentations and line lengths the eye
would experience less strain
because it
does not have to travel to the beginning
of a line.

Figure 16. Internal Vertical Justification.

To lessen the drastic presentation of IVJ, two new arrangements emerged called "square-span" and "spaced-unit". In these two formats the text is separated into short spaced out columns. The difference between the two is the direction in which the type flows. Square-span text flows down a column and then up to the next. Spaced-unit reads from left to right. Researchers found that there was no loss of accuracy in reading with these formats. But, in 1956, a tachistopic test showed that square-span was more legible than the spaced-unit arrangement.[30] Examples of both formats are shown in Figure 17.

The square-span arrangement	reads down the column and then up	to the next column and so on.
The spaced-unit	arrangement reads	from left to right.

Figure 17. Square-Span and Spaced Unit.

Although setting text in the boustrophedonic arrangement, IVJ, square-span and spaced-unit seemed to improve legibility, these arrangements do not make practical use of paper. Therefore, creating books in these formats never became a common practice. The most common legible formats for text are flush left and justified and we have become accustom to such arrangements.

In order to adhere to the rules of word spacing, hyphenation is often used. Hyphenation is the separation of a word at the end of a line. Hyphenation is added only between syllables. Optimal legibility using hyphenation is established by using the following common practices:

1. At line endings, hyphenation must leave at least two characters behind and take at least three forward. (**ex:** fi-nally *not* final-ly)
2. You generally want more characters of a word on the line after the hyphen and do not hyphenate a word shorter than four letters.
3. Avoid three consecutive hyphenated lines.[31]

7.) Page Size, Margins and Columns

For thousands of years, scribes and typographers have been shaping visual spaces. The proportions that kept reoccurring—due to pleasing the eye, the mind and these formats were comfortable for the hand—shaped a vertical rectangle. Shapes like triangles, squares, pentagons, hexagons and octagons were not so pleasing. Thus, the rectangle was adopted as the optimal format and shape for a page.[32]

There is no evidence that exists that relates page size and legibility. The choice of page size has always depended on practical and esthetic judgement. A survey conducted by Paterson concluded optimal page sizes based on a number of publications (Table 6 shows his findings). Paterson found that textbooks (in the 1950's) fell into three groupings: 4x7, 5x7 and 5x8 inches. Foreign Scientific Journals fell into two strong groupings: 5x8 and 6x9 inches. The American Scientific Journals had two groupings: 6x9 and 6x10 inches. Finally, American Non-Scientific Journals had two strong groupings: 6x10 and 8x11 inches. What all these page sizes have in common is that these they all have a ratio of 2:3.

Page Sizes for Various Publications

Width and Height inches	Text Books %	Foreign Journals %	American Science Journals %	American Non-Science Journals %
4x7	28.0	0.5	1.0	0.0
5x7	27.8	0.5	0.0	1.0
5x8	29.9	20.0	6.0	2.0
6x9	4.6	59.5	32.0	15.0
6x10	0.0	4.5	26.5	2.0
8x11	0.0	0.5	1.5	41.0

Table 6. Page sizes.[33]

Unfortunately, this survey also concluded that page size preference depended on having paper stock manufacturers arrive at an agreement on paper size that would minimize waste.[34] The paper industry responded to the need for standardization and came up with basis sizes for different types of paper. These standard sizes (shown in Table 7) were based on the popularity of page size.

Basis Paper Sizes

Book	25"x 38"
Bond	17"x 22"
Newsprint	24"x 36"
Cover	20"x 26"

Table 7. Paper Sizes.

Today, our page sizes are determined by these standards. For example, for optimal use of bond paper we use page sizes of 8 1/2 x 11 or 5 1/2 x 8 1/2 inches. The limitations of basis size in relation to cost will greatly influence our final page size.

After determining page size, other factors like margins and columns become crucial factors in legibility. In general, it has been found that the text of a page should take up fifty percent of the space on a sheet of paper. Tinker found that this fifty percent rule gives the illusion that more space is actually being taken up on a page. He surveyed 928 college students who were asked to estimate the amount of space an average text (book) occupied a page. The majority said sixty to seventy-five percent. This illusion was tested carefully—later by Tinker—and 300 subjects overestimated the fifty percent rule by eighteen percent. When these subjects were told about the fifty percent rule they believe that the rule was justified. A majority of sixty-two percent believed it was important in terms of legibility.

Tinker and Paterson decided to go further with their testing after their initial findings. They wanted to establish how margins were preferred by their subjects. Experiments showed that, in books, using larger inner margins to compensate for book binding was better than even margins. They also found that readers believed that ample margins are justified either in terms of esthetics or improved legibility.[35]

The secrets of a book page can be accurately described by the work of Jan Tschichold who found that the harmony between page size and type area is achieved by both having the same proportions. In 1953, Tschichold determined the framework of ideal proportions in medieval manuscripts—framework that is still used today—shown in Figure 18. Tschichold found that the optimum margins of a page could be determined by drawing a diagonal line from one corner to another and across both pages (see Figure 18). After examining

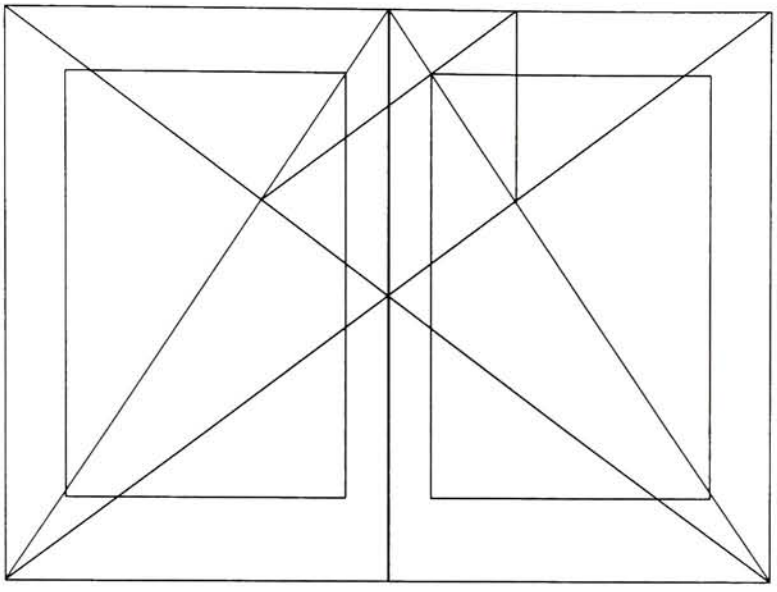

Figure 18. Page proportion and margins.

countless medieval manuscripts, Tschichold rediscovered that the page format of the book and the text block must be equal to be a harmonious unit.[36]

The number of columns on a page is determined by the size of a page and its margins. As earlier documented, the length of a line has an impact on legibility. If a line length is too long, legibility will suffer. Both Tinker and Paterson—along with other experts on legibility—found that research in this area in not necessary. If moderate line lengths are recommended for legibility then line length can be determined by the width of the page. Tests have shown that as the width of a page increases the number of columns will also increase.

Summary

The purpose of a printed page is to be read and understood, to communicate ideas, information, instructions or emotions.[37] When typography became a function of how we communicate, legibility became the most important factor in typography.

Years of empirical and non-empirical research have narrowed down the principles of typography in terms of legibility which have been compiled into Table 8. These guidelines are the backbone of a legible printed page and are the most effective principles of typography used today.

The Most Effective Principles of Typography for the Printed Page	
Typeface	Although the legibility of a type style depends on what we are accustom to, serifs have been found to be the most legible due to their contrasting letter shapes.
Line Length	Moderate line lengths with 60 characters per line is recommended, but, type size and line length are a good place to start calculating line length. Type size=LL; 6pts=9-28; 8pts=14-25; 10pts=14-31; 12-14pts=17-33.
Paragraph Indent	Paragraph indents relate to the length of a line. LL(picas)=Indent(ems) 9-18=1 em 19-23=1.5 ems 24-33=2 ems
Leading	Add 20% of the point size to the line spacing.
Color/Contrast	Black on white is the most legible. Black on yellow is second. The rule for color is that the combination of text and background must have contrast between them.
Type Size	Text: 8-14 points Display: 15+
Text Format	Although IVJ, Square-span and Spaced-unit were found to be the most legible formats, we use flush left or justified—which are legible as long as the white space between characters and words is even—so we consume less paper.
Hyphenation	Hyphenation must leave 2 characters behind and must take at least 3 forward. You generally want more of the word after the hyphen. Avoid three consecutive hyphenated lines.
Page Size	Page size is influenced by the cost of paper involved. A page should be rectangular and in a vertical orientation. 6x9 inches is the most common size for a book page.
Margins	Text and margins should be equal. (50% of a page should be text and 50% should be margins)
Columns	As page size increases the number of columns increases to keep line lengths moderate.

Table 8. Principles of Typography for the printed page.

End Notes for Chapter 2

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2 Rolf F. Rehe, *Typography: How to Make it Most Legible* (Indianapolis, Indiana: Design Research Publications, 1974), 12.

3 Miles A. Tinker, *Legibility of Print* (Ames, Iowa: Iowa State University Press, 1963), 8.

4 John R. Biggs, *An Approach to Type* (London, England: Blanford Press, 1949), 23.

5 Rolf F. Rehe, *Typography: How to Make it Most Legible* (Indianapolis, Indiana: Design Research Publications, 1974), 18.

6 Rolf F. Rehe, *Typography: How to Make it Most Legible* (Indianapolis, Indiana: Design Research Publications, 1974), 21.

7 D.Y. Cornog and F.C. Rose, *Legibility of Alphanumeric Characters and Other Symbols* (Washington, D.C.: U.S. Government Printing Office, 1967), 33.

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9 John R. Biggs, *An Approach to Type* (London, England: Blanford Press, 1949), 23, 30.

10 Miles A. Tinker, "The Relative Legibility of the Letters, the digits, and of Certain Mathematical Signs," *Journal of General Psychology*, 1 (July-October, 1928): 472-496.

11 Miles A. Tinker, *Legibility of Print* (Ames, Iowa: Iowa State University Press, 1963), 49.

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17 Miles A. Tinker, *Legibility of Print* (Ames, Iowa: Iowa State University Press, 1963), 106.

18 Robert Bringhurst, *The Elements of Typographic Style* (Vancouver, British Columbia: Hartley and Marks, 1992), 37.

19 Miles A. Tinker, *Legibility of Print* (Ames, Iowa: Iowa State University Press, 1963), 127.

20 Rolf F. Rehe, *Typography: How to Make it Most Legible* (Indianapolis, Indiana: Design Research Publications, 1974), 31.

21 Miles A. Tinker, *Legibility of Print* (Ames, Iowa: Iowa State University Press, 1963), 130.

22 Miles A. Tinker, *Legibility of Print* (Ames, Iowa: Iowa State University Press, 1963), 136.

23 Donald G. Paterson, *How to Make Type Readable* (New York and London: Harper & Brothers Publishers, 1940), 121.

24 Donald G. Paterson, *How to Make Type Readable* (New York and London: Harper & Brothers Publishers, 1940), 125.

25 Donald G. Paterson, *How to Make Type Readable* (New York and London: Harper & Brothers Publishers, 1940), 125.

26 Donald G. Paterson, *How to Make Type Readable* (New York and London: Harper & Brothers Publishers, 1940), 121.

27 Rolf F. Rehe, *Typography: How to Make it Most Legible* (Indianapolis, Indiana: Design Research Publications, 1974), 28

28 Robert Bringhurst, *The Elements of Typographic Style* (Vancouver, British Columbia: Hartley and Marks, 1992), 26.

29 Herbert Spencer, *The Visible Word: Problems of Legibility, Second Edition* (Lund Humphries, 1969), 38.

30 Herbert Spencer, *The Visible Word: Problems of Legibility, Second Edition* (Lund Humphries, 1969), 40.

31 Robert Bringhurst, *The Elements of Typographic Style* (Vancouver, British Columbia: Hartley and Marks, 1992), 40.

32 Robert Bringhurst, *The Elements of Typographic Style* (Vancouver, British Columbia: Hartley and Marks, 1992), 130.

33 Donald G. Paterson, *How to Make Type Readable* (New York and London: Harper & Brothers Publishers, 1940), 83.

34 Donald G. Paterson, *How to Make Type Readable* (New York and London: Harper & Brothers Publishers, 1940), 84.

35 Miles A. Tinker, *Legibility of Print* (Ames, Iowa: Iowa State University Press, 1963), 113.

36 Jan Tschichold, *The Form of the Book* (Point Roberts, Washington: Hartley & Marks, 1991), 62.

37 Herbert Spencer, *The Visible Word: Problems of Legibility, Second Edition* (Lund Humphries, 1969), 41.

Chapter 3

Hypothesis

The principles of typography for a printed page are not transferrable to the screen, but, changing most of these principles will enable text presentation on the screen to be as legible as a printed page.

Chapter 4

Methodology

The first step to prove the hypothesis was to establish recommended typographic specifications for on-screen viewing. By evaluating extensive research studies on the legibility of computer monitors or CRT's, conclusions can be made about how text should be set and arranged for on-screen viewing and reading.

The legibility of text on a computer monitor can be broken down into two categories: *traditional* and *modern*. Based on recent literature on this subject, traditional factors consist of luminance, contrast, character height, character width and so on. Modern factors include the physical characteristics of monitors such as flicker, refresh rate, resolution, CRT size and orientation.[1] When traditional and modern factors are united with the practice of reading text on a screen, the characteristics of legible typography change. Most of what we know about creating a legible page can no longer be applied.

Emphasis

When establishing what should be tested for typographic principles for the screen, one principle has been purposely left out: *emphasis*. To create a typographical distinction in a paragraph of text, *emphasis* is usually a strong typographic application. As stated in Chapter 2, *italics*, **bold** and CAPS are used to make a word or phrase stand out from all the others. This variation in style adds *voice* to a line of text. But these changes in style do not have the same effect in

electronic documents. Unfortunately, the italic style decreases legibility so much that it is simply un-usable as a method of emphasis.[2] The use of capital letters in electronic text is often associated with yelling and should not be used frequently. Which leaves us with bold as the only method—besides color which will be discussed later—for emphasis.

Choosing a Typeface

Before explaining which category of type is appropriate for on-screen text, it is important to understand some of the characteristics and background of digital type. First of all, the notion of digital typography can be defined as the method of creating and rendering characters using classical typography and computer science.[3] Font designers today design a font on paper and regenerate the font design on a computer. During the late 70's early 80's, fonts were stored by photocompositors by outline descriptions. Type could not be viewed on the screen because the outlines were too large for display devices. When resolution independent page description languages were introduced this soon changed. Font manufacturers saw the need to evaluate both output device characteristics and screen font design. The outcome of this evaluation lead to the font technology we know today which consists of *bitmaps* and *outlines. Outlines* can be defined as a mathematical representation of a glyph which can be scaled to any size. Primarily, *outlines* are used for high to medium resolution devices. A *bitmap* is a digital representation of a glyph. *Bitmaps* are made up of pixels which can be on or off depending on the shape of the character. Fonts on a computer monitor represent *bitmaps.*

Since bitmaps are essential to this thesis, outlines need not be discussed in detail. One important note about outlines is that bitmaps are created by using a sampling of the outline. The first obstacle when rendering type on a screen is that most low resolution devices such as a CRT cannot provide enough samples to reproduce the information in the original design. This "under-sampling" causes loss of high frequency information.[4] The result is called "aliasing" or "jaggies". Figure 19 shows a sampling of pixels rendered from an outline.

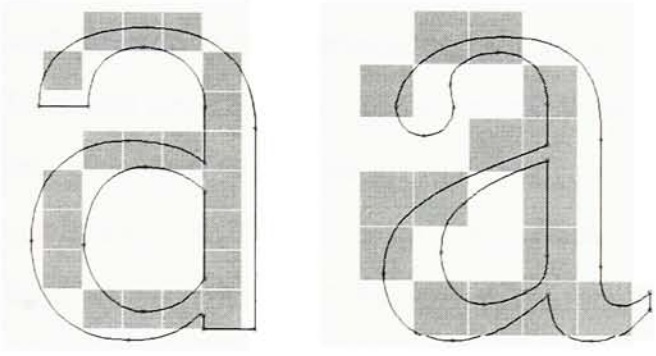

Figure 19. Aliased type.

Charles Bigelow and Kris Holmes examined the attributes of screen type and designed the typeface *Lucida* which was made to compensate for on screen viewing. They examined factors of CRT's and bitmap rendering to find what characteristics were needed to ensure legibility in an "aliased image environment".[5] In their study, Bigelow and Holmes found that serif shapes pose many problems on CRT's. At low screen resolutions hairline serifs were lost and high contrast serifs became unrecognizable. When bracketed serif letters decreased in size they became slab serifs. They also found that bracketed serifs require more screen rebuild time. The *Lucida* typeface was designed to compensate for these factors. *Lucida* has low contrast serifs with a serif stem ratio of 2:1, which prevents deterioration of type at reasonably small sizes.

In the same study for *Lucida*, Bigelow and Holmes found that low resolution systems encourage large x-heights. Due to the complex middle portions of lowercase letters, more resolution would be required to render small x-heights. Small x-heights become filled in and letters become illegible—as shown in Figure 20.

Figure 20. Small x-height bitmaps.

Based on the *Lucida* study and the factors of digital type we see that low resolution screen fonts will never be exact reproductions of their high resolution counterparts. Therefore, the font we choose for legible type will differ from print to screen. The deterioration of serif typefaces on screen displays interrupts their otherwise legible form. To prevent loss of character shape sans serif or slab serif-with large x-heights—are recommended for on-screen reading. In this study a variety of 4 typefaces—*Helvetica, Times, Officina and Lucida*—have been chosen in consideration of factors previously stated in this thesis.

Helvetica: is a very common sans serif with a large x-height.

Times: is the most common serif typeface used on all home computers and has a large x-height.

Officina: is a typeface which has un-bracketed serifs, a low serif to stem ratio and large x-height.

Lucida: was one of the first typefaces created for the screen. Using this typeface will test if observers prefer type designed for the screen.

Type Size

Technologies for digital type have enabled type sizes 14 points and up to be quite legible. Unfortunately, most of us don't read headlines only. Most text type sizes are between eight to twelve points in size. One of the latest technologies called "anti-aliasing," has addressed the issue of screen font rendering by creating the illusion of no "jaggies" by adding interference around the edges of characters—shown in Figure 21. But, while anti-aliasing works wonders for headlines it does not work well with 10 point type—and all other text sizes. Another downfall of anti-aliasing is that screen rebuild time triples. Finally, ergonomics studies have also shown that anti-aliasing simply compounds the problems of ill-defined edges which add more stress on your eyes.[6] For this reason "aliased" or bitmap fonts will be used when testing preferences for the screen.

Figure 21. Anti-aliased Type.

When choosing a type size for the screen, the main issue to address is, again, resolution. Practical evidence has shown that screens with 72 dpi resolutions are 1 or 2 decimal orders of magnitude too low to render fonts—at text sizes—with optimal quality.[7] Because of this, larger text sizes like 12-15 will be much better suited for presenting type on screen.[8] In this study the following text sizes were tested: 12pts, 13pts, 14pts, and 15pts.

Leading

When applying the optimal leading of a printed page to the screen, there is often obvious problems with the traditional rules of typography. If text is set solid—point size equals line space—on the screen, the space between the descenders of the first line and the ascenders of all the lines which follow will often overlap each other. This is an effect caused by the low resolutions involved with on-screen viewing. In print conditions adding 20 percent more leading would cure this problem. But, 20 percent on a computer monitor is sometimes not enough to prevent this overlap. "When tops and bottoms of letters come within one or two pixels, they confuse the eye and inhibit reading".[9] With this in mind, the test for this thesis included the following leading variations:

20% leading will be tested to show if people prefer the suggested leading for print.

30% more leading will add more space and will prevent ascenders and descenders from overlapping.

40% will add more white space between ascenders and descenders.

50% to test if even more white space is preferred.

Line Length

The traditional rule of line length is that 60 characters per line should suffice for optimal legibility. This number is usually balanced with factors like type size, leading and the width of the text area involved. In print, columns are used in various print media—depending on the size of the publication—to optimize legibility. Magazines optimize the legibility of articles by using multiple columns

on pages that are generally 8 1/2 x 11 inches. But, in most situations, computer monitors cannot support pages of this size. The use of columns is usually not necessary. Columns are also a rarity due to the larger point sizes used to optimize legibility on the screen. Because columns are not used, web page designers and electronic publishers have more space to work with. The 60 character per line (cpl) rule is usually applied to the screen, if the typeface allows it. However, a study done in 1986 on the legibility of type on video text displays showed that reducing line length by 20% increased legibility.[10] In this thesis four line lengths were tested, starting with the maximum recommended for print and decreasing each test by ten characters: 60 cpl, 50 cpl, 40 cpl, and 30 cpl.

The results of the four tests described above were used to set up the remaining tests described below. The preferences for test session one were: Lucida, 15 points, 50 percent leading and sixty characters per line—which resulted in a line length of thirty-eight picas.

Paragraph Indent

The clarity of a new paragraph is generally defined with a paragraph indent. This thesis tested legibility of indents by varying the size of white space added to the first line of text. The test was set up using the rule of thumb found in Chapter 2, twice the the rule of thumb indent and half of the rule of thumb indent. Based on the general rule of thumb for indent—that larger line lengths require greater indents—the author increased the indent for the preferred line length of thirty-eight picas, to three ems. The other indents which were tested were one and a half em spaces and six em spaces.

Text Format

Low resolution monitors always have trouble rendering accurate interword and inter-character spacing. That is, the space between each word in a line and the space between the characters in each word. As stated in Chapter 2, the human visual system is very sensitive to space. Unfortunately, most computer applications do not control the rendering of a line of text for on-screen viewing. Because of this lack of control, the simplest text format is recommended. Formats such as flush right and centered—for continuous text—are not recommended. Since the legibility of text decreases when viewing on low resolution devices, the only logical formats to choose for testing were *flush left* and *justified*. This thesis tested for these two formats only.

Hyphenation

The test for hyphenation was set up to find if readers prefer to read text with or without hyphenation.

Margins

This test was set up to find the optimal margins for on-screen viewing and reading. Observers were shown four variations of margins: using the 50% rule (50% text and 50% white space), more that 50% margins, less than 50% margins, and no margins.

An unavoidable change for this test had to be made. Since the typographic specifications needed to follow the observers preferences, page size had to be

varied to test for margins. The following page sizes were determined based on a text block of 6 5/8 x 3 1/4 inches:

% of Margins	Page Size (inches)
50%	13 x 6 1/2
+50%	14 x 7
-50%	9 x 5 1/2
0%	6 5/8 x 3 1/4

Color

Probably the most complex and misunderstood attribute of viewing text on a screen is the use of color. One could do a thesis on this subject alone. Presently there are no rules about color use on a CRT, but, based on what we know about color and CRT's we can produce general guidelines that will enable easier reading on the screen. In 1993 a study of *Color in Computer Graphics* was done under the auspices of the UK Advisory Group on Computer Graphics. Eight pages were created to test the appearance of color and the effects of color combinations.[11] The following is a list of what they found:

1 The appearance of color is related to the color of the surrounding region. Generally, colors look darker and smaller against white and colors look lighter and larger against black—shown in Figure 22.

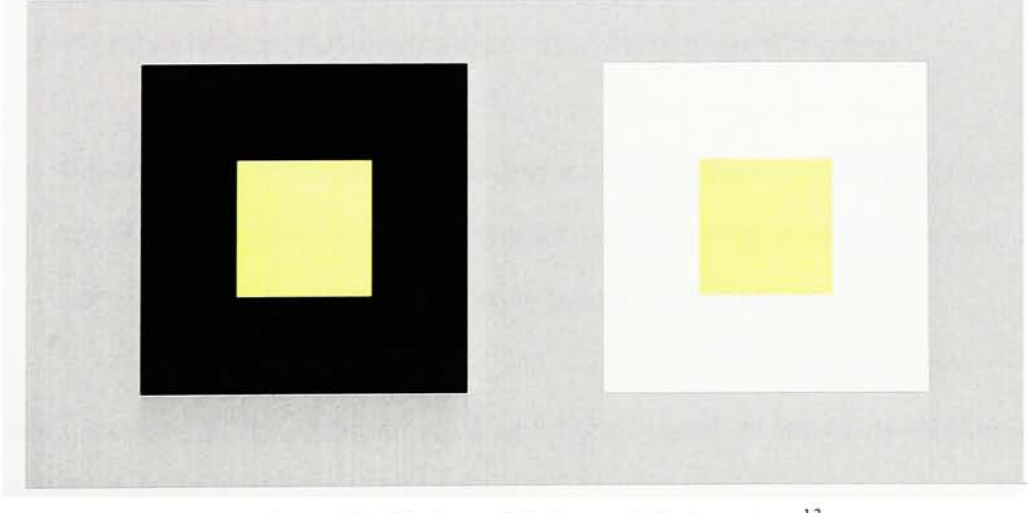

Figure 22. Illusions of lighter and darker colors.[12]

2 The appearance of color is effected by its surrounding areas. This study tested the effect of grey on a yellow and blue background. The grey line in Figure 23 —although it is the same color in both squares—appears to be different.

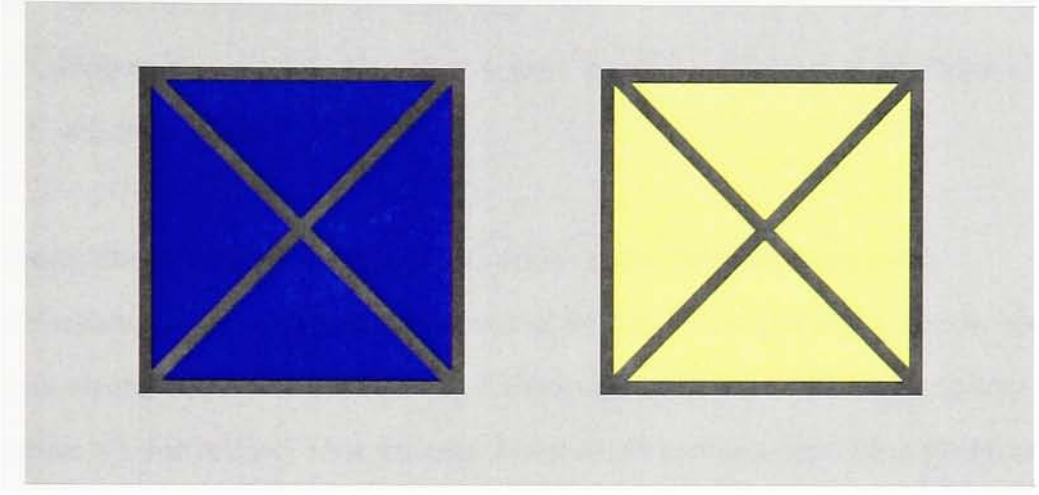

Figure 23. The Effects of Surrounding Color.[13]

3 Color depends on the condition under which it is viewed.[14] Ideally there should be neutral colors in the background—grey is the least distracting.

4 Color in print and on screen should be used in conjunction with other visual attributes: position, shape, size, orientation and texture.

5 Color evokes responses of emotion and can trigger memories. Colors that are warm like red, orange and yellow imply action or warning. Cool colors such as green, blue and grey imply passivity and safety.

The outcome of this study resulted in a list of recommendations relating to legibility of color for on-screen viewing.

1 Start with black and white and add color sparingly.
2 Use bright colors for emphasis and weaker colors in the background.
3 To avoid constant refocusing and eye fatigue, do not use extreme color pairs such as red and blue or yellow and purple.
4 Avoid red and green because up to 10% of the population is color blind.
5 Opponent colors work well together. A color combination like blue and yellow is good.

Using the recommendations above about color, the following color combinations have been chosen for testing in this thesis: For *high contrast,* black text on white, white text on black and black text on yellow (the author chose pantone 101 for yellow) were chosen. For *medium contrast,* light blue (pantone 300) and pale yellow (pantone 101) were used. For a *low contrast* test black text on a 50% black background was chosen.

Setting up the test

The documents were set up for the paired comparison method for evaluation. Using a paired comparison will prove that the principles of typography for the screen are valid. This method compares a percentage of the observers who prefer one stimuli over another. Thirty observers were randomly selected to evaluate these electronic pages. Their ages ranged between twenty to fifty-five years old. Each observer spent ten to fifteen minutes to complete the tests.

Before the two test sessions were created, a standard viewing condition had to be established. The factors involved were monitor size, resolution and document

size. For this experiment, a 15 inch monitor was used. This size represents the most common monitor being sold to the average user today. The base number of pixels will be 640 x 480. This resolution created a "worst-case" scenario for on-screen viewing on a 15 inch monitor. After the monitor was setup, a document size was established. The size which fits best into the viewable area of a 15 inch monitor using Adobe Acrobat is 8 1/2 x 5 1/2 inches. This page size can be viewed at 100%, with no adjustments or scrolling—which would otherwise interfere with the testing. The observers were asked to read the following instructions before starting the test:

> Please look at the following pages of text. Each test page is lettered **A** through **D**. Please choose which paragraph is more legible to you. There are no right or wrong answers so its okay to guess! To choose an answer click **once** on the letter of choice found at the top of the page. You will then be navigated to the next test.

Each test was set up in *Adobe Acrobat 3.0*. Each observer was asked to evaluate a page and choose which block of text was more legible. They chose by clicking on the letter that corresponded to their answer (see Appendix A and B for sample test pages). All test files were linked to each other using *Acrobat's* file linking feature. Each link was associated with the answer to the previous question. For example, test 1 tested for typeface. If the observer chose typeface **A**, they clicked on the letter **A**. The next test that appeared—a test for type size—used typeface **A**. Using file linking ensured that each test was customized according to the observers

preferences. In order to keep track of the observers answers, a small footer was placed on the lower left corner of the page to mark the answers (see samples found in Appendix A and B).

The testing was performed in two sessions in order to reduce the number of documents that had to be created. The first session tested for optimal typeface, type size, leading and line length. The cumulative results from session one were used to set up session two which tested for paragraph indent, text format, hyphenation, margins and color.

End Notes for Chapter 4

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2 Paul Kahn and Krzysztof Lenk, "Typography for the Computer Screen: Applying the Lessons of Print to Electronic Documents," *The Seybold Report on Desktop Publishing*, 7, 11 (July 5, 1993): 12.

3 Roger D. Hersch, *Visual and Technical Aspects of Type* (Cambridge: Cambridge University Press, 1993). 56.

4 Charles Bigelow and Kris Holmes, "The Design of Lucida: an Integrated Family of Types for Electronic Literacy," *Text Processing and Document Manipulation*, (1986): 2.

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6 James Felici, "A Bitmap a Day . . . Keeps the Doctor Away," *Typofile Magazine*, (May 1997): WWW.

7 Charles Bigelow, "Font Design for Personal Workstations," *Byte*, (January, 1985): 256.

8 Paul Kahn and Krzysztof Lenk, "Typography for the Computer Screen: Applying the Lessons of Print to Electronic Documents," *The Seybold Report on Desktop Publishing*, 7, 11 (July 5, 1993): 5.

9 Paul Kahn and Krzysztof Lenk, "Typography for the Computer Screen: Applying the Lessons of Print to Electronic Documents," *The Seybold Report on Desktop Publishing*, 7, 11 (July 5, 1993): 9.

10 F.L. Van Nes, "Space, Colour and Typography on Visual Display Terminals," *Behavior and Information Technology*, 5, 2 (1986): 103.

11 Linda Macaulay, *Human-Computer Interaction for Software Designers* (Oxford, UK: The Alden Press), 58.

12 Linda Macaulay, *Human-Computer Interaction for Software Designers* (Oxford, UK: The Alden Press), 59.

13 Linda Macaulay, *Human-Computer Interaction for Software Designers* (Oxford, UK: The Alden Press), 59.

14 Linda Macaulay, *Human-Computer Interaction for Software Designers* (Oxford, UK: The Alden Press), 59.

Chapter 5

Results

As stated in Chapter 4, the testing portion of this thesis was broken down into two testing sessions. A total of 308 documents were created and nine different tests were completed by each observer. Because the testing for this thesis was set up to find a cumulative result of each observer, it was not time consuming or difficult to tabulate the results. The final observers choices were marked in the lower left footer of each test page (See Appendix A and B). The final test page contained the cumulative results for each observer. To obtain the results of the tests, tables were created (see Appendix C and D) by adding up the observers preferences found on the test page footer. These tables were used to evaluate the results. From these tables percentages were calculated and the data was placed into the following pie charts.

The summary that follows will explain if the test results correspond with the authors hypothesis—*the principles of typography for a printed page are not transferrable to the screen, but, changing most of these principles will enable text presentation on the screen to be as legible as a printed page.*

Test Session 1

In the choice of a *typeface*, sixty-seven percent of the observers chose the typeface Lucida—a typeface designed for the screen. The second typeface of choice—by twenty-seven percent—was Helvetica. The typeface Times was never chosen as a

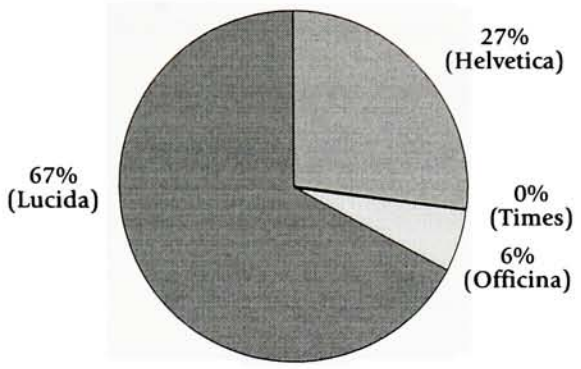

Figure 24. Results for Typeface.

preferred typeface. In print, the typeface Times would be considered the most legible, therefore the rule of thumb for print will be different than for on-screen reading.

The results for the test for *type size* are shown in Figure 25. Thirty-seven of the observers preferred the largest type size—15 points—presented on screen. Thirty percent of the observers chose 13 point type. The smallest type size, which was 12 points, was the least preferred type size. Since the observers preferred fifteen point type—which, in print would be considered a display type size—the range of text sizes for legible reading on the screen will differ from that of a printed page.

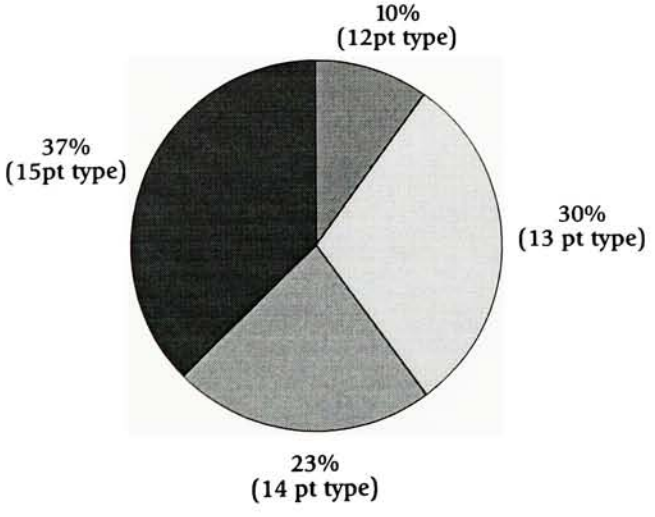

Figure 25. Results for Type Size.

The test for the optimal *leading* resulted in forty-seven percent of the observers choosing fifty percent added lead. The second leading choice was thirty percent added lead. Since the optimal leading for print is 20%—which only sixteen percent of the observer chose—the rule of thumb for print can not be applied to the screen.

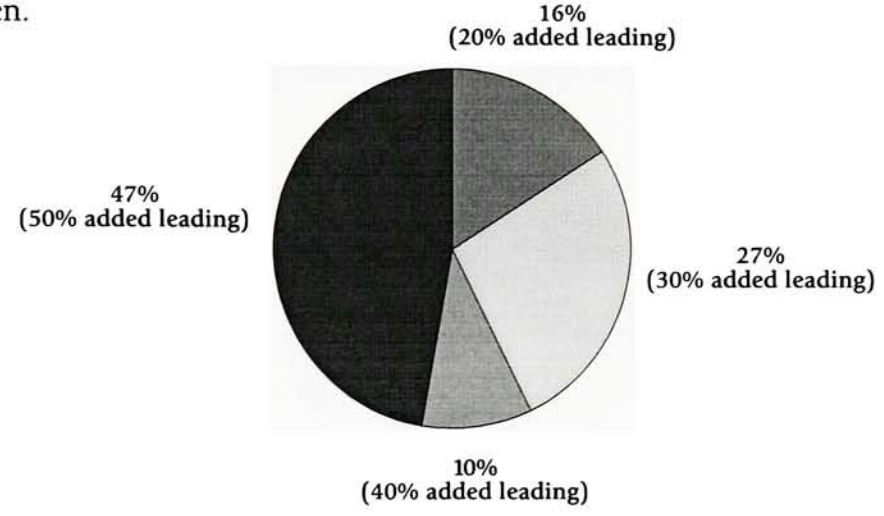

Figure 26. Results for Leading.

Figure 27 shows that most of the observers preferred sixty characters per line for the *line length* test. The second choice—different by only four percent—was fifty characters per line. The shortest line length was the least preferred. Because sixty characters per line is the rule of thumb for print, this principle will not change.

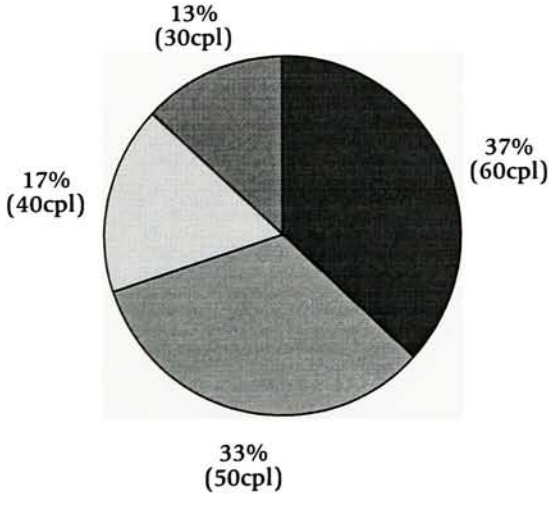

Figure 27. Results for Line Length.

Test Session 2

For the preferred choice of a *paragraph indent,* thirty-seven percent of the observers chose a one and a half em space indent—half of the recommended indent for print. Thirty-three percent of the observers chose a six em indent which was twice the size recommended for print. The least chosen indent was the rule of thumb for print—a three em indent. The rule for paragraph indent for on-screen reading will change.

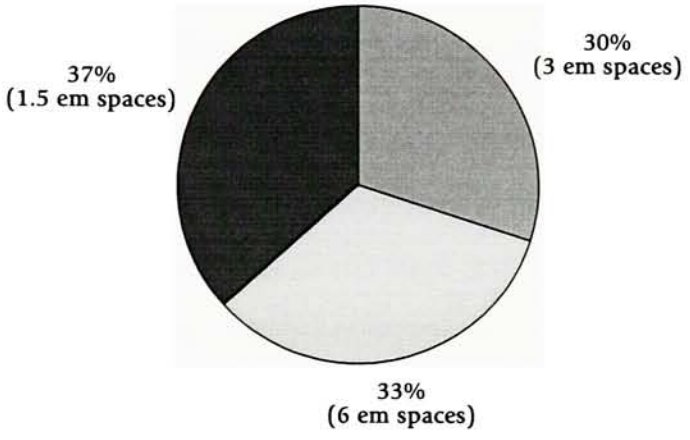

Figure 28. Results for Indent.

The two choices for *text format* were justified and flush left as shown in Figure 29. Fifty-seven percent of the observers preferred justified text. Most observers preferred text which was even on both sides, rather than ragged on the right side. The test for *hyphenation* resulted in fifty-seven percent of the observers preferring text with hyphenation.

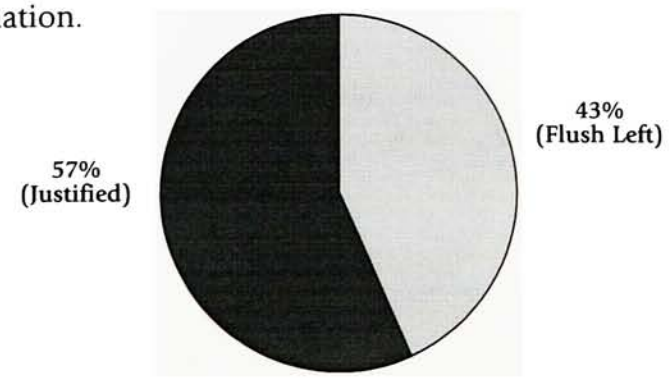

Figure 29. Results for Text Format.

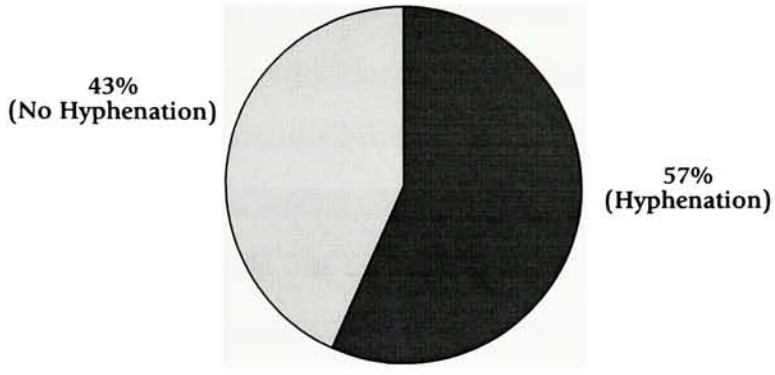

Figure 30. Results for Hyphenation.

For the preferred *margins* testing, zero observers preferred the rule of thumb for a printed page—which was fifty percent margins and fifty percent text. Observers commented that the page size became too large and they preferred **not** scrolling the page as they were reading. Eighty-seven percent of the observer chose less than fifty percent margins. They preferred a page that almost fit the size of the screen with seventy-five percent text content. The optimal page size as a result of this test was 9 3/4 x 5 1/4 inches. This test proved that the principles for both page size and margins must be different for on-screen reading.

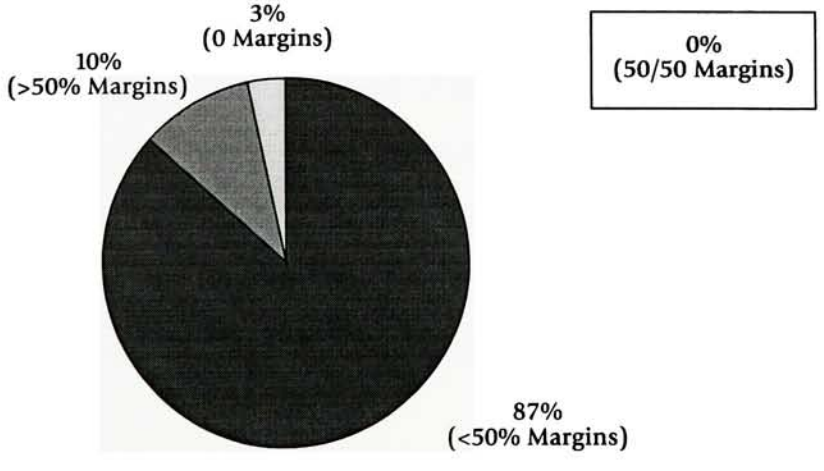

Figure 31. Results for Margins.

The results of the *color* testing are shown in Figure 32. Fifty-four percent of the observers chose black text on a white background. The second color combination preferred was black text on a yellow background. Both of these choices correspond with the choice of legible color for the printed page. Observers preferred high contrast between text and background. The principle for color combinations in print are the same applied to the screen.

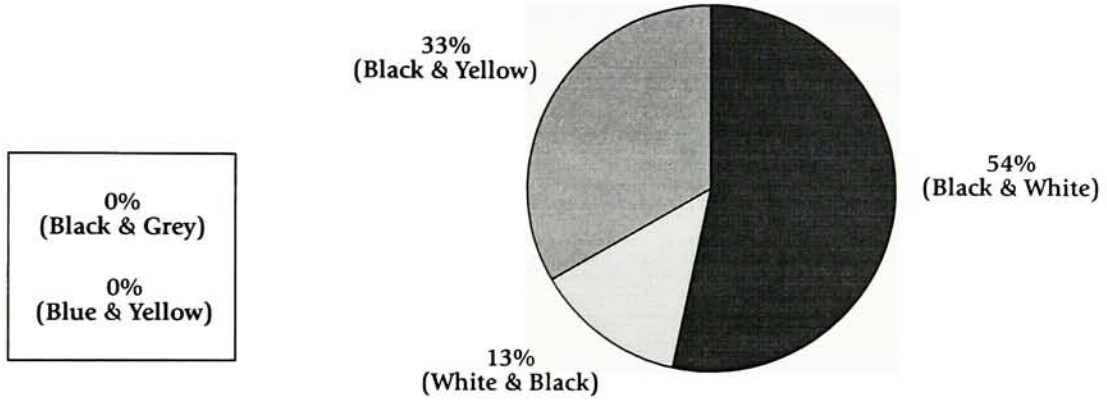

Figure 32. Results for Color.

Further Analysis of the Results

After the cumulative results of the tests were tabulated and percentages calculated, a further analysis was conducted. The observers of this thesis were fifteen males and fifteen females between the ages of twenty and fifty-five. For the further analysis, the cumulative results of the testing were broken down into two separate tables (see Appendix F) to find if male and female observers had different preferences for on-screen text. The results are as follows

For the choice of *typeface,* the results were the same. Both males and females preferred Lucida over the other typefaces tested. There were also no differences in

the choice of *type size* or *leading*. Both male and female observers preferred fifteen point type with fifty percent added lead. For the preference in *line length*, there was a slight difference. Females preferred sixty characters per line while the choice for males—sixty and fifty characters per line— was equal.

The analysis of *paragraph indent* showed that most females preferred a three em space indent—the rule of thumb for print. The most preferred indent for males was one and a half em spaces, which was half of the rule of thumb for print. Both male and female observers preferred a justified *text format* with *hyphenation* and less than fifty percent *margins*. Finally, the test for preferred *color* showed a more significant difference. Most females preferred black text on a white background while most males chose black text on a yellow background.

Overall Results

Based on the results of the testing for this experiment, using the paired comparison method, the hypothesis has been proven to be correct. Out of nine separate tests, seven principles must be changed to ensure legibility for on-screen reading. By further analysis of the results of the testing, the author found that there were no significant differences between what was preferred by male versus female observers.

Chapter 6

Summary and Conclusions

The objective of this thesis was to establish a new set of typographic principles for the screen. By evaluating the current practices of typography for print and applying them to today's computer monitors, it is obvious that new practices must be determined. The testing in this thesis was done, not only to prove that these principles must change, but also to find what these new principles of typography should consist of. (For a comparison of the principles of typography for the printed page versus the screen see Appendix E).

The results of the testing in this thesis showed that the rules about the choice of a typeface, type size, leading, paragraph indent, text format, hyphenation and margins are different for the screen. When choosing a typeface, the best choice is a typeface specifically designed for the screen. Typefaces such as Lucida—recently two new faces Verdana and Georgia—have been designed for the screen. The range of text sizes must increase for optimal legibility on the screen. Eight to eleven point type were ruled out of the testing for this thesis because most typefaces become "filled in" and illegible at these sizes. The new type size range for text is twelve to fifteen—fifteen was the most preferred size. Fifty percent added leading was found to be the most legible choice. Paragraphs of text were too crowded using the twenty percent rule of thumb for print. Paragraph indents were more legible when half of the rule of thumb for print was applied. Justified text proved to be more legible than flush left because there is more space between

each character in a line. Text with hyphenation was found to be more legible on the screen because it allows the line of text to be more evenly spaced and line endings are less ragged when using a flush left format. The 50/50 rule about margins for a printed page should never be applied to the screen. First of all, due to the limitations of page size, increasing the page size larger than the monitor size can hinder legibility. Readers don't like to scroll or zoom when reading text on the screen. The rules for margins and page size are closely related to each other. First, choose a page size that fits into the screen view without any interference. For a 15 inch monitor the optimal page size determined in this thesis was 9 x 5 1/2 inches. Second, set your margins so that there less than 50% white space in the margin.

The choice of color and line length are the only two print principles that stay the same for on screen reading. Black text on a white background and black text on a yellow background were the most preferred color combinations for the screen—no different than for printed matter. It is good to use black text on white and add color sparingly for emphasis. Finally, the line lengths for text are most legible at sixty characters per line.

To sum up the results of this thesis, the formulas for the most legible principles of typography for the screen is shown below:

Overall Results:

15/22.5, 60cpl, Lucida, 1.5em Indent, Justified, Hyphenation, Black on White.

Results for Females:

15/22.5, 60cpl, Lucida, 3em Indent, Justified, Hyphenation, Black on White.

Results for Males:

15/22.5, 50-60cpl, Lucida, 1.5em Indent, Justified, Hyphenation, Black on Yellow.

Sample pages using these formulas are found in Appendix G.

Testing all the color combinations available on a computer monitor was out of the scope of this thesis. Recommendations for further study include a closer study of different color combinations for text on the screen. One text format was not tested in this thesis because it is not a common format for print: *Internal Vertical Justification,* found in Chapter 2. However, this format has been found to be the most legible in print. Further testing should be done on *Internal Vertical Justification* since paper is not an issue with electronic documents.

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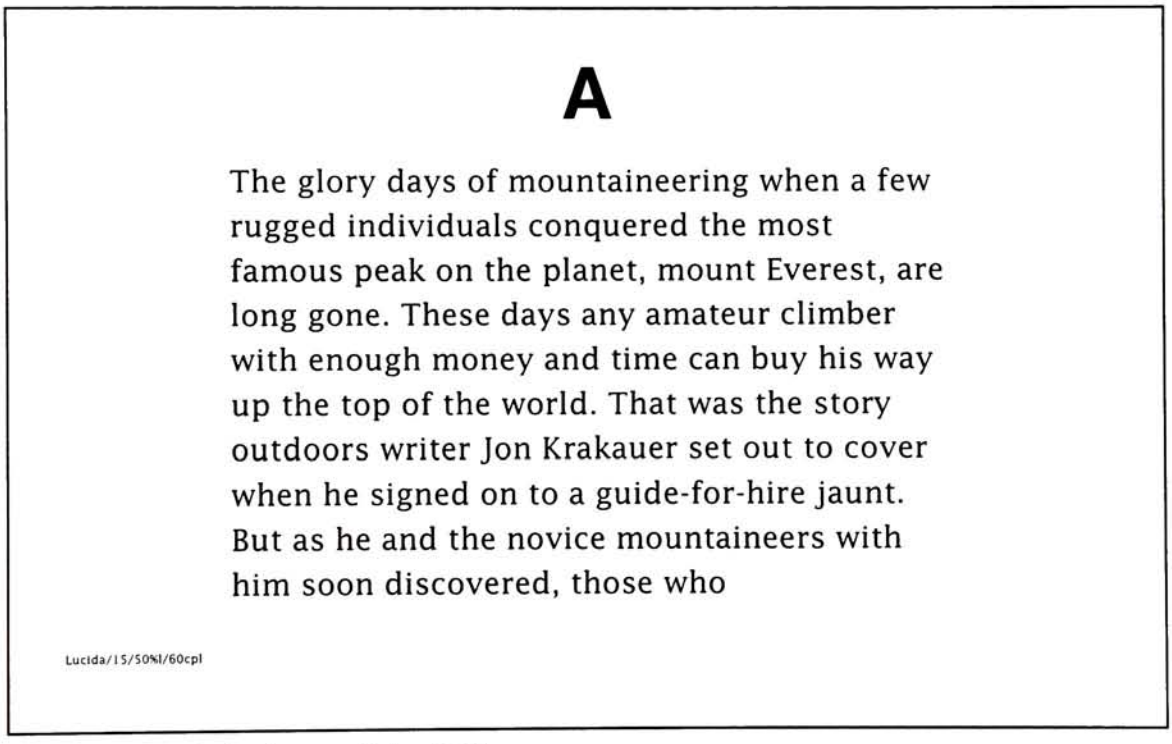
Appendix A

Appendix A

Sample of Test 1

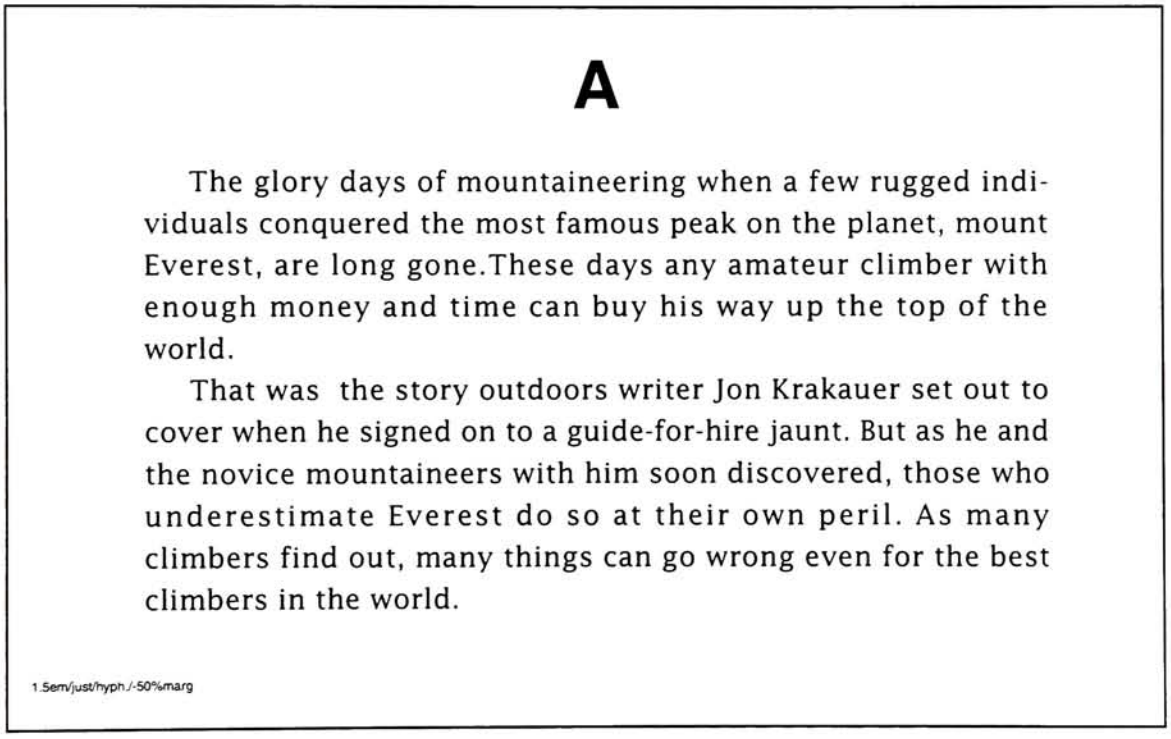


The above sample has been scaled to 75%.

Appendix B

Appendix B

Sample of Test 2



The above sample has been scaled to 70%.

Appendix C

Appendix C

Results of Test Session 1

Observer Results: Typeface

	Helvetica	Times	Officina	Lucida
Observer-1	x			
Observer-2				x
Observer-3	x			
Observer-4				x
Observer-5	x			
Observer-6				x
Observer-7	x			
Observer-8			x	
Observer-9				x
Observer-10	x			
Observer-11				x
Observer-12				x
Observer-13				x
Observer-14				x
Observer-15				x
Observer-16				x
Observer-17				x
Observer-18	x			
Observer-19				x
Observer-20	x			
Observer-21				x
Observer-22				x
Observer-23				x
Observer-24				x
Observer-25				x
Observer-26			x	
Observer-27				x
Observer-28				x
Observer-29				x
Observer-30	x			
Total	**8**	**0**	**2**	**20**

Table 9. Observer Results: Typeface.

Appendix C

Results of Test Session 1

Observer Results: Type Size

	12 points	13 points	14 points	15 points
Observer-1		x		
Observer-2		x		
Observer-3			x	
Observer-4				x
Observer-5		x		
Observer-6		x		
Observer-7			x	
Observer-8				x
Observer-9			x	
Observer-10	x			
Observer-11			x	
Observer-12			x	
Observer-13				x
Observer-14				x
Observer-15				x
Observer-16		x		
Observer-17				x
Observer-18		x		
Observer-19				x
Observer-20		x		
Observer-21	x			
Observer-22		x		
Observer-23				x
Observer-24				x
Observer-25			x	
Observer-26				x
Observer-27	x			
Observer-28				x
Observer-29		x		
Observer-30			x	
Total	**3**	**9**	**7**	**11**

Table 10. Observer Results: Type Size.

Appendix C

Results of Test Session 1

Observer Results: Leading

	20%	30%	40%	50%
Observer-1	x			
Observer-2		x		
Observer-3		x		
Observer-4				x
Observer-5		x		
Observer-6				x
Observer-7		x		
Observer-8				x
Observer-9		x		
Observer-10				x
Observer-11			x	
Observer-12	x			
Observer-13		x		
Observer-14				x
Observer-15				x
Observer-16			x	
Observer-17				x
Observer-18	x			
Observer-19		x		
Observer-20				x
Observer-21				x
Observer-22	x			
Observer-23				x
Observer-24				x
Observer-25		x		
Observer-26	x			
Observer-27				x
Observer-28				x
Observer-29			x	
Observer-30				x
Total	**5**	**8**	**3**	**14**

Table 11. Observer Results: Leading.

Appendix C

Results of Test Session 1

Observer Results: Line Length

	60 cpl	50 cpl	40 cpl	30cpl
Observer-1	x			
Observer-2				x
Observer-3		x		
Observer-4		x		
Observer-5		x		
Observer-6			x	
Observer-7		x		
Observer-8			x	
Observer-9	x			
Observer-10			x	
Observer-11	x			
Observer-12			x	
Observer-13	x			
Observer-14		x		
Observer-15		x		
Observer-16	x			
Observer-17				x
Observer-18		x		
Observer-19	x			
Observer-20			x	
Observer-21		x		
Observer-22	x			
Observer-23				x
Observer-24		x		
Observer-25	x			
Observer-26	x			
Observer-27	x			
Observer-28				x
Observer-29		x		
Observer-30	x			
Total	**11**	**10**	**5**	**4**

Table 12. Observer Results: Line Length.

Appendix D

Appendix D

Results of Test Session 2

Observer Results: Paragraph Indent

	3 em spaces	6 em spaces	1 1/2 em spaces
Observer-1	x		
Observer-2	x		
Observer-3	x		
Observer-4		x	
Observer-5	x		
Observer-6	x		
Observer-7		x	
Observer-8			x
Observer-9			x
Observer-10		x	
Observer-11			x
Observer-12		x	
Observer-13		x	
Observer-14		x	
Observer-15		x	
Observer-16			x
Observer-17		x	
Observer-18			x
Observer-19	x		
Observer-20	x		
Observer-21		x	
Observer-22		x	
Observer-23	x		
Observer-24	x		
Observer-25			x
Observer-26			x
Observer-27			x
Observer-28			x
Observer-29			x
Observer-30			x
Total	**9**	**10**	**11**

Table 13. Observer Results: Paragraph Indent.

Appendix D

Results of Test Session 2

Observer Results: Text Format

	Flush Left	Justified
Observer-1	x	
Observer-2		x
Observer-3	x	
Observer-4		x
Observer-5	x	
Observer-6	x	
Observer-7	x	
Observer-8	x	
Observer-9	x	
Observer-10		x
Observer-11	x	
Observer-12		x
Observer-13		x
Observer-14	x	
Observer-15	x	
Observer-16		x
Observer-17	x	
Observer-18		x
Observer-19		x
Observer-20		x
Observer-21		x
Observer-22	x	
Observer-23		x
Observer-24		x
Observer-25		x
Observer-26	x	
Observer-27		x
Observer-28		x
Observer-29		x
Observer-30		x
Total	**13**	**17**

Table 14. Observer Results: Text Format.

Appendix D

Results of Test Session 2

Observer Results: Hyphenation

	With Hyphenation	No Hyphenation
Observer-1	x	
Observer-2	x	
Observer-3		x
Observer-4		x
Observer-5		x
Observer-6	x	
Observer-7	x	
Observer-8		x
Observer-9		x
Observer-10	x	
Observer-11	x	
Observer-12		x
Observer-13	x	
Observer-14		x
Observer-15	x	
Observer-16	x	
Observer-17	x	
Observer-18		x
Observer-19	x	
Observer-20	x	
Observer-21	x	
Observer-22	x	
Observer-23	x	
Observer-24		x
Observer-25		x
Observer-26		x
Observer-27	x	
Observer-28		x
Observer-29		x
Observer-30	x	
Total	**17**	**13**

Table 15. Observer Results: Hyphenation.

Appendix D

Results of Test Session 2

Observer Results: Margins

	50/50	<50%	>50%	No Margins
Observer-1		x		
Observer-2		x		
Observer-3		x		
Observer-4		x		
Observer-5		x		
Observer-6		x		
Observer-7				x
Observer-8		x		
Observer-9		x		
Observer-10			x	
Observer-11			x	
Observer-12		x		
Observer-13		x		
Observer-14		x		
Observer-15		x		
Observer-16		x		
Observer-17		x		
Observer-18		x		
Observer-19		x		
Observer-20		x		
Observer-21		x		
Observer-22		x		
Observer-23		x		
Observer-24		x		
Observer-25		x		
Observer-26		x		
Observer-27		x		
Observer-28			x	
Observer-29		x		
Observer-30		x		
Total	**0**	**26**	**3**	**1**

Table 16. Observer Results: Margins.

Appendix D

Results of Test Session 2

Observer Results: Color

	Black/White	White/Black	Black/Yellow	Black/Grey	Blue/Yellow
Observer-1	x				
Observer-2	x				
Observer-3			x		
Observer-4			x		
Observer-5	x				
Observer-6	x				
Observer-7		x			
Observer-8	x				
Observer-9	x				
Observer-10		x			
Observer-11			x		
Observer-12	x				
Observer-13	x				
Observer-14	x				
Observer-15			x		
Observer-16			x		
Observer-17	x				
Observer-18			x		
Observer-19	x				
Observer-20			x		
Observer-21	x				
Observer-22	x				
Observer-23			x		
Observer-24		x			
Observer-25			x		
Observer-26	x				
Observer-27			x		
Observer-28		x			
Observer-29	x				
Observer-30	x				
Total	**16**	**4**	**10**	**0**	**0**

Table 17. Observer Results: Color.

Appendix E

Appendix E

Principles of Typography for Print vs Screen

	Print	Screen
Typeface	Although the legibility of a type style depends on what we are accustom to, serifs have been found to be the most legible due to their contrasting letter shapes.	First choice should be a typeface designed for the screen. The second choice should be a Sans Serif or Slab Serif typeface with a large x-height.
Line Length	Moderate line lengths with 60 characters per line is recommended, but, type size and line length are a good place to start calculating line length. Type size=LL; 6pts=9–28; 8pts=14–25; 10pts=14–31; 12–14pts=17–33.	60 characters per line is also recommended for the screen. Longer line lengths are more legible on the screen than shorter ones.
Paragraph Indent	Paragraph indents relate to the length of a line. LL(picas)=Indent(ems) 9–18=1 em 19–23=1.5 ems 24–33=2 ems	Smaller indents are preferred on the screen. Use half of the rule of thumb for print: LL=Indent: 9-18pts=1/2 em 19-23pts=3/4 em 24-33pts=1 em 33-40=1 1/2 ems
Leading	Add 20% of the point size to the line spacing.	Add 50% of the point size to the line spacing.
Color/Contrast	Black on white is the most legible. Black on yellow is second. The rule for color is that the combination of text and background must have contrast between them.	Black on white is the most legible. Black on yellow is second. Males prefer black on yellow, females prefer black on white. High contrast is more legible than low contrast color combinations.
Type Size	Text: 8–14 points Display: 15+	Text: 12–15 points Display: 16+
Text Format	Although IVJ, Square-span and Spaced-unit were found to be the most legible formats, we use flush left or justified—which are legible as long as the white space between characters and words is even—so we consume less paper.	Justified text is more legible when used in conjunction with hyphenation to avoid uneven spaces between words. Second choice is Flush Left with hyphenation to avoid an extremely ragged right edge.
Hyphenation	Hyphenation must leave 2 characters behind and must take at least 3 forward. You generally want more of the word after the hyphen. Avoid three consecutive hyphenated lines.	Hyphenation rules are the same as printed material. Hyphenation is highly recommended for the screen due to the even spaces that result when hyphenation is applied.
Page Size	Page size is influenced by the cost of paper involved. A page should be rectangular and in a vertical orientation. 6x9 inches is the most common size for a book page.	Page size is influenced by screen size. The best page size is one that fits into the monitor screen view without scrolling or zooming.
Margins	Text and margins should be equal. (50% of a page should be text and 50% should be margins)	Text and Margins should not be equal. Less than 50% margins is recommended for the most legible on-screen reading.
Columns	As page size increases the number of columns increases to keep line lengths moderate.	Columns are not recommended for the screen due to the large point sizes used for on-screen text.

Table 18. Observer Results: Print versus Screen.

Appendix F

Analysis of Results: Male versus Female

Typeface

Males	
Helvetica	2
Times	0
Officina	2
Lucida	11

Females	
Helvetica	6
Times	0
Officina	0
Lucida	9

Table 19. Typeface: Male versus Female.

Appendix F

Analysis of Results: Male versus Female

Type Size

Males	
12 points	1
13 points	3
14 points	5
15 points	6

Females	
12 points	2
13 points	6
14 points	2
15 points	5

Table 20. Type Size: Male versus Female.

Appendix F

Analysis of Results: Male versus Female

Leading

Males	
20%	3
30%	4
40%	1
50%	7

Females	
20%	2
30%	4
40%	2
50%	7

Table 21. Leading: Male versus Female.

Appendix F

Analysis of Results: Male versus Female

Line Length

Males	
60 cpl	5
50 cpl	5
40 cpl	2
30 cpl	3

Females	
60 cpl	6
50 cpl	5
40 cpl	3
30 cpl	1

Table 22. Line Length: Male versus Female.

Appendix F

Analysis of Results: Male versus Female

Paragraph Indent

Males	
3 em	3
6 em	5
1 1/2 em	7

Females	
3 em	6
6 em	5
1 1/2 em	4

Table 23. Paragraph Indent: Male versus Female.

Appendix F

Analysis of Results: Male versus Female

Text Format

Males	
Flush Left	6
Justified	9

Females	
Flush Left	7
Justified	8

Table 24. Text Format: Male versus Female.

Appendix F

Analysis of Results: Male versus Female

Hyphenation

Males	
With Hyphenation	9
No Hyphenation	6

Females	
With Hyphenation	8
No Hyphenation	7

Table 25. Hyphenation: Male versus Female.

Appendix F

Analysis of Results: Male versus Female

Margins

Males	
50/50	0
<50	12
>50	2
0	1

Females	
50/50	0
<50	14
>50	1
0	0

Table 26. Margins: Males versus Females.

Appendix F

Analysis of Results: Male versus Female

Color

Males	
Black and White	5
White and Black	2
Black and Yellow	8
Black and Grey	0
Blue and Yellow	0

Females	
Black and White	11
White and Black	2
Black and Yellow	2
Black and Grey	0
Blue and Yellow	0

Table 27. Margins: Male versus Female.

Appendix G

Appendix G

Result of All Observers

It was the most astounding drop in crime in recent history. In 1996, compared with 1993, New York City declined 49 percent, robberies 43 percent, burglaries 39 percent and grand larceny 32 percent.

This plummeting crime rate is "simply breath-taking," says the New York Times. The turnabout is all the more remarkable because only a few years ago the New York City police Department was a demoralized and paralyzed force.

Ever since the police corruption scandals of the early 70's, there are less officers. Police officers have withdrawn from enforcing public-order law against aggressive panhandelers, graffiti, vandals and the like. This abdication emboldened young hoods, teaching them that crime pays. It also fed public fear.

The above sample has been scaled to 75%.

15/22.5, 60cpl, Lucida, 1.5em Indent, Justified, Hyphenation, Black on White.

Appendix G

Result of Male Observers

It was the most astounding drop in crime in recent history. In 1996, compared with 1993, New York City declined 49 percent, robberies 43 percent, burglaries 39 percent and grand larceny 32 percent.

This plummeting crime rate is "simply breath-taking," says the New York Times. The turnabout is all the more remarkable because only a few years ago the New York City police Department was a demoralized and paralyzed force.

Ever since the police corruption scandals of the early 70's, there are less officers. Police officers have withdrawn from enforcing public-order law against aggressive panhandelers, graffiti, vandals and the like. This abdication emboldened young hoods, teaching them that crime pays. It also fed public fear.

The above sample has been scaled to 75%.

15/22.5, 50-60cpl, Lucida, 1.5em Indent, Justified, Hyphenation, Black on Yellow.

Appendix G

Result of Female Observers

It was the most astounding drop in crime in recent history. In 1996, compared with 1993, New York City declined 49 percent, robberies 43 percent, burglaries 39 percent and grand larceny 32 percent.

This plummeting crime rate is "simply breath-taking," says the New York Times. The turnabout is all the more remarkable because only a few years ago the New York City police Department was a demoralized and paralyzed force.

Ever since the police corruption scandals of the early 70's, there are less officers. Police officers have withdrawn from enforcing public-order law against aggressive panhandelers, graffiti, vandals and the like. This abdication emboldened young hoods, teaching them that crime pays. It also fed public fear.

The above sample has been scaled to 75%.

15/22.5, 60cpl, Lucida, 3em Indent, Justified, Hyphenation, Black on White.