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cont.

Visible Language

A lot of design has happened in the 50 years since *Visible Language* was founded: typesetters – gone; desktop publishing – a passing blip; computers – moved from desktop to pocket. The term graphic design had hardly entered the dictionary before the discipline started to consider renaming itself visual communication design or just communication design. Because communication continues to grow in quantity and importance there's no reason to disbelieve in a promising future for a communication design discipline. What the promising design future looks like is, as always, sketchy. A well-known 20th century Danish proverb states that predictions are easy except when they involve the future and George Santayana famously warned of the trouble that awaits failure to examine the past. If we take Santayana's statement less as a warning than as a prescription to guide action, we might reflect thoughtfully on the past in order to plan our steps today to help shape a future the Danes say is so difficult to predict. Reflecting on the past may not make predictions easier, but it might make them more realistic.

To celebrate its 50th year *Visible Language* will revisit themes from the journal's past to help chart the design discipline's future. This issue features articles by Meredith Davis, Sharon Poggenpohl, and myself commenting on design's direction, design journals, and design research. As a special homage to the journal's roots in typographic research issue 50.2 will revisit typography and see what we have learned in the past 50 years and project where typographic study should be going next. Issue 50.3 will look at *Visible Language* in light of design history and theory with a similar aim: to reflect on the past to help guide and inspire the future: reflecting back – reflecting ahead. Reflecting in the sense of thinking deeply or carefully about something and at the same time suggesting the visual nature of much of human cognition and the essential visual nature of design. Reflection is a physical process wherein light or energy is thrown back from a surface. We learn about ourselves through reflection. We see things in a new light, from a new vantage point, and if the mirror is placed properly we can see not just where we've been but where we are going: around the corner we have not yet turned.

This year we are devoting part of the journal to not predicting the future but to shaping it. We can't wait to see what they'll say about our efforts in 2065!

Calculating Line Length: an arithmetic approach

Ernesto Peña

Abstract

This paper introduces an arithmetic formula for the calculation of text line length (also referred to as line width) for roman alphabet from 1) the length of the alphabet in lowercase, 2) a value for the desired character density and 3) a mathematical constant. A short-range study with this formula has shown a margin of error of less than 5% in common serifed text typefaces. The potential application of this formula in both print and digital editorial products could be diverse, from the approximate calculation of pages in a book to the establishment of control parameters in responsive web pages. Moreover, this formula would allow designers to make decisions about formal aspects on reading devices based on principles of readability and reading experience.

KEY WORDS:

Typography, Editorial Design, Metrics, Line length, Character density

Introduction

The understanding of what makes a text readable has been a concern across several fields of study since —at least— the last century, although the records of the use of the term *readability* started by the first half of the XIX century (Michel et al., 2011; "Readability, N.," 2014). By the mid 1960s, the term *readability* was applied to different conceptions, referring on the one hand to the ease of comprehension of the text either due to the complexity of the topic or the writing style and on the other to formal aspects such as the layout of the information or the typeface (Klare, 1963). Rather than considering the properties of the font such as size of ascenders and descenders, x-height, color and stroke weight, the design of the serif and other distinctive features, which have been encompassed within the concept of *legibility* (Gaultney, 2001), the line length might be one of the most —if not *the* most— relevant factor of readability in a text.

Nanavati and Bias (2005) reported the existence of at least 100 years of research on line length and gave an overview of the results of such research from the studies conducted by Tinker and Paterson since the late 1920s to the impact thereof in digital media applications (Miles A. Tinker, 1928; Paterson and Tinker, 1929; M. A. Tinker and Paterson, 1929; M. A. Tinker and Paterson, 1931; Paterson and Tinker, 1940; Paterson and Tinker, 1943; Paterson and Tinker, 1946; Miles A. Tinker, 1963a; Miles A. Tinker, 1963b; Miles A. Tinker, 1966). The results are diverse not only in respect to the data, but also respect to the format that researchers have historically employed to express them, given either in continuous data units such as millimeters, centimeters, or picas, or in discreet data units such as words per line (WPL) or characters per line (CPL). The implications of the choice of units go beyond the mere format. As a readability value, the metric length of the line itself is trivial unless it is combined with others such as the width of the characters, the font size (Bringhurst, 2004, 27), or the quantity of words or characters that are contained within that length. If any, the information that could be considered from this sole value would be the reading area and the necessity of the reader to follow up with the head while reading. However, even the latter would require other data such as the distance between the reader and the reading space or the font size. In contrast, values such as the number of words or characters, also known as word- or character "density" (Dyson, 2004, 379), would be independent of the chosen typeface or its metrics.

Inherently more convenient than the continuous data units, and despite the fact that they have been used interchangeably (e.g., Spencer, 1969, 35), there are crucial differences between the use of WPL and CPL. For instance, in the case of the former, the number of words that a fixed line length could contain would depend on the average of letters per word, a value that would vary between languages and even genres. A self-conducted study by De Buen (2014) reported the a difference in the average of characters per word between English and Spanish in narrative and non-narrative genres:

TABLE **1**. Difference in average letters per word between English and Spanish, in narrative and non-narrative (De Buen, 2014, 157)

	Narrative	Non-narrative
English	3.46	4.09
Spanish	3.92	3.97

Considering these findings, within English alone, the character density of 12 words from a non-narrative piece would be higher than 14 words from a narrative piece on two equally long text lines. It is likely that this and other circumstances have provoked CPL to be largely favored as a line length unit. Several contemporary authors and researchers (e.g. Bringhurst, 2004; De Buen, 2014; Dyson, 2004) have employed this measure routinely enough to claim that if there is something close to a standard in regards to line length, it might be CPL.

The use of the character density as a criterion for the line length is not free of challenges. Unlike with what happens with continuous data units where the line length can be easily induced with any text processor or self-publishing software, the resources for calculating the character density are limited: from all the scholars that have embraced CPL as a unit for determining line length, only few (i.e., Bringhurst, 2004; De Buen, 2014) have provided resources for the calculation thereof. Bringhurst (2004) recommends staying within a range of 45 to 75 CPL "for a single-column page set in a serifed text face in a text size", with 66 characters including spaces, "widely regarded as ideal" (26). To induce these metrics, Bringhurst has proposed a "Table of Average Character Count per Line" (29) that uses the length of the lowercase alphabet (LCA) in typographic points (1/12 inches) set in the typeface and font size that would be used in the text.

TABLE **2**. Fragment of the table of average character count per line by Bringhurst (2004). The extreme left column indicates the approximate length of the LCA in points (90). The following numbers of that row indicate the approximate character density (36, 43, 50…), and the top row indicates the approximate length of the text line in picas (10, 12, 14…). The original table includes an indication of the ranges of CPL recommended by Bringhurst.

	10	12	14	16	18	20	22	24…
				…..				
90	36	43	50	57	**64**	72	79	86…

Although the origin of Bringhurst's criteria is unclear, Nanavati and Bias (2005) report on a study conducted by Dyson and Kipping (1998) in which lines of 55 characters were perceived by the participants as easier to read on screen than lines of 25 and 100 characters. In this case, the number computed of characters does not include spaces. Nevertheless, if De Buen's calculations on the average of characters per word in English are accurate, the inclusion of spaces in Dyson and Kipping's would result in lines of between 68 and 70 (55 + [52 ÷ 4.09/3.42 – 1] characters, falling relatively close to Bringhurst's suggestion.

For his part, De Buen (2014) argues that the length of the text line should depend not only on the requirements of the layout of the text but also on different factors among which should be the proficiency of the reader, which would be gauged within a range between novice and expert[1]. According to De Buen, the character density in a document for a novice reader should range between 34 and 60 characters (including spaces) with 45 as optimal. A document for an expert reader should range between 45 and 80 characters with 60 as optimal. The method offered by De Buen (2014) for the calculation of line length from the character density suggests to obtain the value of the LCA and subsequently multiply it by 1.75 to obtain the optimal line length, denominated *l*. This new value should be then multiplied by 0.75 to determine the minimum length, denominated *n*, and by 1.5 to determine the maximum, denominated *m*. Arguably, the origin of these values respond to an approximate extrapolation from the 26 characters of the LCA:

Optimal	26×1.75=45.5	45
Minimum	45.5×0.75=34.125	34
Maximum	45.5×1.5=68.25	60

I would argue that despite the effectiveness of these resources for the calculation of the line length, they still posit a few operative limitations. On the one hand, the "Table of Average Character Count per Line" (Bringhurst, 2004, 29) is comprehensive enough to cover a broad range of possible scenarios: from 10 to 160 CPL, 80 to 360 points of LCA (in increments of 5 points) and 10 to 40 picas of line length (in increments of 2 picas). However, the calculation of the line length depends completely on the access to the table. On the other hand, the mathematical formulas introduced by De Buen (2014, 216) give more freedom to the designer, but its reach is limited to the prescribed ranges. The proposal presented here seeks to provide one possible resource to overcome these limitations.

A Proposal

What I propose is an arithmetic formula that could be used to calculate the metric space within which a particular character density can be applicable. This formula considers different scenarios in print or digital media, regardless of the chosen criteria for the definition of the character density within a text line. It is constituted by three components: the LCA of the chosen typeface at the size and spacing that would be used including the space character (LCA'), the desired character density (Cρ), and a mathematical constant that I have provisionally denominated S. This formula could be expressed as follows: $LCA' \times C\rho(S) = Ll$. These components are intended to take account of the horizontal metric features of the chosen font (width, size), the linguistic

1 De Buen (2014) uses the labels bajo lector and alto lector, translated literally as 'low reader' and 'high reader', respectively (221).

features of the text and the criterion of the designer. The denominated LCA' and the S constant are described below.

EXTENDED LOWER CASE ALPHABET (LCA')

As with the previously mentioned devices (Bringhurst's table, De Buen's formulas), the formula presented here employs LCA as a starting point. The idea of using the length of the lower case alphabet as a reference for the estimation of the efficiency of a typeface is not new: Legge and Bigelow (2011) have qualified it as "a traditional typographic measure" (4) which inclusion in typographic specimens used to be a common practice (e.g., American Type Founders, 1953, 1968; Mergenthaler Linotype Company, 1951) along with —in some cases— the characters that a pica could contain. Traditionally, the LCA is obtained by writing the basic characters of the Roman lowercase alphabet without accents, diacritics or digraphs [abcdefghijklmnopqrstuvwxyz] (Bringhurst, 2004; Legge and Bigelow, 2011) and measuring the length of the string of characters, whether with physical instruments or digitally. I would assume that the aim of this exercise is to consider all the different widths that the characters in the lower case alphabet have. Therefore, if that is the case, even when there are languages in which the basic alphabet includes digraphs or accented characters, when digraphs are combinations of already existing characters, it would be assumed that they are metrically identical to another one and omitted. Accented characters would be omitted as well as accents; diacritics do not usually affect the width of the character, and their inclusion in the LCA string would yield duplicated values[2]. However, in cases in which the alphabet or idiomatic practices of a given language include letters that are not part of the previously introduced string of characters (e.g., æ, ß, or l·l), such characters would have to be included within the LCA string for they have a width of their own. Based on these criteria and on the fact that the space character might be the most common in written manifestations of practically every language[3], I would argue that the LCA should include the space character as well. I refer here to this extended version of the LCA as LCA'. The inclusion of non-Roman and space characters and the way their inclusion would affect the formula is discussed below.

THE S CONSTANT

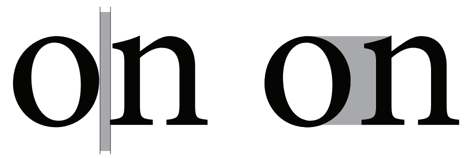
The third component of the formula is a number that derives from a version of the LCA that includes the space character (LCA'), and therefore, it would change depending on the features of the basic alphabet of the language in

2 For instance, in Spanish, the ch and ll used to be considered part of the alphabet until its recent removal. Their inclusion in the LCA string would yield an incidence of three l (l and ll), two c and two h (c, h and ch). In turn, the ñ is still considered a letter of the alphabet, but being metrically identical to an n, its inclusion would duplicate a width metric in the string of characters ("Exclusión de 'ch' y 'll' del abecedario," n.d.).

3 De Buen (2014) reports that this is surely the case in Spanish and English.

which the text is laid out. However, this constant is intended to be calculated only once for each scenario and used recursively, that is, once for basic Roman alphabet, once for German, etc. Here, for illustrative purposes, I focus mainly on the basic Roman alphabet, but the same principle could be applied to any other. The S constant is the result of counting the inter-word and inter-character metric spaces (as opposed to the optical spaces) within the LCA as characters themselves, and dividing the resulting number by 1.

FIGURE 1.

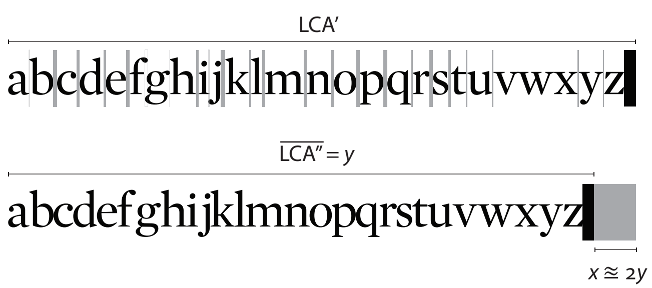


On the left, the inter-character metric space. On the right, inter-character optical space.

The outcome of this operation is a number that multiplied by the LCA' would give the average width of a single character considering the inter-character space, providing a unit accountable for both characters and space by treating space as if it was a character and getting an average of both categories (characters and space). The procedure followed for the acquisition of this number is described as follows:

1. The LCA' was composed with a given typeface and its length measured.
2. The metric spaces between characters were removed to obtain a new inter-character space-less LCA' denominated LCA''. The average width of the characters in LCA'' is determined and subsequently used to measure the metric difference between LCA'' and LCA'.
3. This difference, determined in LCA'' average characters, is added to the LCA' characters.

FIGURE 2.



First row: Lower case alphabet plus the space character, denominated LCA'. Indicated in gray is the inter-character spacing. Second row: The calculation of the average of the LCA' without inter-character spaces, denominated LCA''. This average is subsequently used to measure the inter-character spacing.

4. This new number of characters divides one. The 26 characters of the alphabet and the space sum 27 characters, but as the inter-character space units depend on the design of the typeface, it would vary between fonts. I have found that, among professional serif fonts for continuous reading, this number tends to be close to two, which would give a total of 29 characters. This value responds to a general estimation to which I have arrived after applying the previously described protocol to several typefaces, and it is by no means exact or infallible. During my own tests I have found typefaces in which this number is closer to one (e.g., MT Dante) or to three (e.g., Fedra serif A, Proforma), but I still have not found any typeface that yields an average of inter-character space smaller or larger that this range. However, it is worth pointing out that despite the variance of this value in some typefaces, the formula introduced here presents a relatively small margin of error (±5%), even when applied to typefaces in which the number resulting of the previously described operation is closer to 1 or 3, including those mentioned before. The best possible scenario might be to calculate this number for every typeface used in a document and to keep a personal record, but I would consider the formula provided here is —as it is— a fairly good starting point.

The rounded quotient of the division of 1 by 29 results in what I have denominated the S constant: 0.0345, which arguably applies to most serif typefaces in languages with basic roman alphabet, in attention to the exceptions described in *Extended Lower Case Alphabet (LCA')*. This number multiplied by the LCA' and the desired character density (the amount of characters that the designer wants to fit in the text line) give the length needed to fit the required character density in the same units of the LCA'. The number of characters that the line length result of the application of the formula would fit responds to the criteria of the designer and the requirements of the text and its format, hopefully informed by the pertinent research. For instance, to calculate the line length to fit a desired density of characters of Proforma at a size of 10 points would require laying out the 26 characters of the Roman alphabet plus one space character (LCA')[4]. Assuming that the LCA' is 126.15 pt. (10p6.15) and that the desired density is 80 characters, the operation would be as follows:

$$126.15 \text{ pt.} \times \mathbf{80}(0.0345) = 348.17 \text{ pt.} \ (29\text{p}0.17)$$

Applying a density of 40 to the same data, the result would be:

$$126.15 \text{ pt.} \times \mathbf{40}(0.0345) = 174.08 \text{ pt.} \ (14\text{p}6.08)$$

For an extended Roman alphabet, or the use of characters beyond the 26 of the Roman alphabet such as the German eszett (ß), a similar criterion could be applied, but it would require to add the extra characters to the LCA and to modify the S constant by adding the extra number of characters. Applying these changes to the previous example, the LCA' of

4 For ease of measurement, the space character added to the LCA should be anywhere within the string of characters except for the beginning or the end.

132.10 (11p0.10) (abcdefghijklmnopqrstuvwxyz ß) laid out in Proforma 10, the S constant would have to be modified to a rounded 0.0333 to consider the new character (1/30). Assuming that the desired densities are 80 and 40, the operations would be as follows:

$$132.10 \text{ pt.} \times \mathbf{80}(0.0333) = 351.91 \text{ pt. } (29p3.91)$$

$$132.10 \text{ pt.} \times \mathbf{40}(0.0333) = 175.95 \text{ pt. } (14p7.95)$$

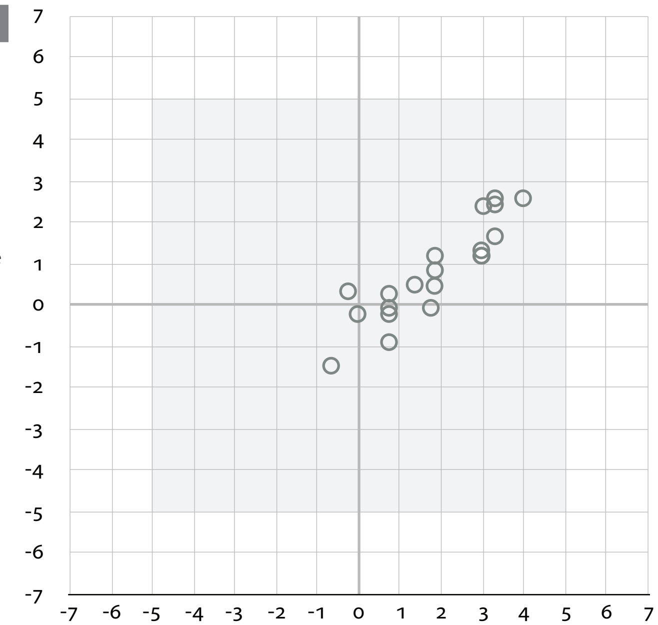
A Short-range Study

To test the effectiveness of the formula presented here, I performed a simple study: I took the first 20 serif typefaces for continuous reading that I found installed in my computer at the moment (most of them system fonts) and applied the formula to calculate the line length for a density of 65 and 45 characters, values chosen for mere illustrative purposes. The protocol was applied to a single paragraph of a placeholder text consisting of 6500 characters obtained from a public website ("Lorem Ipsum"). In every case, the text was laid out ragged (aligned to the left) at a size of 10 pt., and the average was obtained by dividing the number of characters by the number of lines. As the purpose was to measure the density of characters within a line, the last line was omitted from the average calculation when the text did not fully reach the right margin. The results of this exercise showed that all the operations stayed within a margin of difference of 4% between the desired density and the character density resulting of the calculation.

TABLE 3.
Results of applying the formula to 20 serif fonts for continuous reading: The first column lists the typeface, the second lists the value of the LCA', the third and fourth, the percentage of deviation from the desired character densities, 65 and 45 respectively.

Typeface	LCA' pt.	σ (%) 65 C	σ (%) 45 C
Adobe Caslon	119.60	1.84	0.84
Adobe Garamond	115.70	1.74	-0.07
Baskerville	119.60	1.83	0.46
Cambria	128.60	2.96	1.19
Century	137.80	-0.26	0.33
Chaparral	122.80	1.84	1.19
Charter	129.90	0.73	-0.22
Dante MT	118.08	3.01	2.39
Fedra Serif A	151.70	-0.03	-0.22
Fournier	110.70	3.29	1.66
Georgia	132.00	0.73	0.27
Hoefler Text	125.80	1.35	0.49
ITC Mendoza	130.60	-0.67	-1.47
Mercury G1 roman	130.60	3.29	2.43
Minion	120.90	2.97	1.19
Palatino	135.40	3.29	2.58
Proforma	126.90	3.97	2.58
PT Serif	132.90	0.73	-0.07
Scala	125.45	0.73	-0.90
Times New Roman	121.75	2.96	1.32

FIGURE 3.
A scatterplot based on the results of the study. On the *x* axis, the deviation of the result of the application of the formula for a desired density of 45 characters per line. On the *y* axis, for a desired density of 65 characters. The inner square delimits a 5% of deviation. As shown in this table, most of the results of the operations fell into slightly higher numbers, but never over 5%.



Conclusion

The formula presented here does not pretend to be the ultimate resource to line length calculation from character density; I would consider it to be a reference instead. There are in fact conditions for which this formula or any other resource might not be effective, such as justified text or very low character densities. Regardless of whether or not this formula is helpful or accurate in the conditions for which it was meant, the factors that might have an influence on the character density, and therefore on the line length, might be too many to take into account in a single arithmetical resource. A few of these factors have been already listed here, and I would argue that some of them are circumstantially taken into consideration within this formula, but there are many others that would require more complex protocols. A particularly complicated factor that has been only partially discussed here is language. Bringhurst (2004) has addressed the fact that the features of a particular language have (or should have) an impact on the way a text is laid out. According to Bringhurst (2004), highly inflected languages like Spanish would require less inter-word space than less inflected languages such as English or German. This feature would be easily taken into consideration in the formula presented here as the space is part of the string of characters that compose the LCA'. De Buen (2014) has pointed out that because the frequency of use of characters varies among languages, this would have an impact in the calculation of the character density. To be able to accommodate this factor within the formula presented here, the LCA' would have to consider not only the width of the characters but also their frequency, which might be doable by measuring the characters widths individually and modifying this number accordingly to frequency. However, this would result in a very intricate method. The difference between such hypothetical method and the one presented here might be minimal, although this is subject of further investigation. I would argue that beyond the formula itself, having a dynamic arithmetic approach might well open a door to other possibilities, such as the development of digital tools which could easily take into account factors that seem too problematic to be considered for a shorthand method, as this formula pretends to be.

Future endeavors

De Buen's (2014) contentions on the relation between the reader experience and the character density within a text line is appealing and a possible avenue for further research, but until this research is given and its results published, it might be possible to focus not on the reader but on the intended reader by gauging the readability level of specific content through readability formulas. In a recent study, Begeny and Greene (2014) tested 8 of the most popular readability formulas for determining their effectiveness in calculating the difficulty of reading materials. The findings show that despite extensive use in several fields, the success of their sample of formulas on such a task is questionable except for the Dale-Chall formula: Grade = (0.1579 × percent unfamiliar words) + (0.0496 × word/sentence) + 3.6365. The only resource outside of the text itself that this formula employs is a list of 3000 words publicly accessible (e.g., "Dale-Chall Easy Word List Text File" 2014); there are online resources for the calculation of readability by this formula (e.g., Scott, n.d.) and others. According to Begeny and Greene (2014), this formula was identified as "a valid measure of text difficulty level" (210) from grade 4 and above. I would argue that whatever the formula employed for its calculation by finding the relation between readability and character density and applying this criterion to the desired character density value ($C\rho$) of the formula introduced here, the two understandings of readability presented at the beginning of this paper (namely ease of comprehension and formal aspects) could potentially converge in a single device such as an digital application that could calculate not only the readability of a text but also the line-length that would be appropriate for laying out such content.

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