

THINKING ON PAPER:

HINDU-ARABIC NUMERALS IN EUROPEAN TYPOGRAPHY

Liz C. Throop

ABSTRACT

Western typography involves the 26 letters, punctuation marks and numerals as a whole “expanded alphabet.” Between the 11th and 16th centuries the hindu-arabic numerals entered that alphabet, causing greater numeracy, much like the growth in literacy during that period. Europeans had to overcome ignorance and prejudice toward a foreign number system, but also had to adapt the numerals’ visual forms to fit in with their existing alphabet. Westerners were at last able to work out calculations “on paper,” which helped Europe move from a primarily oral to modern graphical culture. While the numerals we use today remain residually “foreign” in some ways, their introduction is a significant part of the history of Western typography.

INTRODUCTION

THE PRACTICE OF TYPOGRAPHY INVOLVES WORKING WITH THE 26 LETTERS, punctuation marks and numerals more or less as a whole “expanded alphabet,” yet most histories of typography focus on the letters with little or no mention of the hindu-arabic numerals. The origination of the numerals in India and their migration to Arabic cultures has been dealt with extensively elsewhere. What follows is an account of how these characters became part of our writing system after repeated introductions; how they were adapted to fit in with our written letterforms; and how their incorporation played a part in the transition from the primarily oral culture of medieval Europe to modern graphical culture.

IMPERFECT NUMBER SYSTEMS

PRIOR TO THE RENAISSANCE, EUROPEANS USED SEVERAL SEPARATE SYSTEMS to count and do calculations. A farmer might have counted his sheep by carving notches in a wooden tally stick using a system of marks specific to his family or region. A merchant might have counted on his fingers, toes and other body parts to do addition and subtraction. A monk might have calculated the dates of upcoming Easter celebrations by moving stones on a counting board (a table that served as a sort of abacus) while another monk transcribed the dates

onto parchment using roman numerals. These various methods were adequate for counting and recording simple operations, but none of the systems lent themselves to working out extended calculations “on paper.” Those few who could do calculations on the counting board constituted a powerful elite, and the vast majority of Europeans could have been described as innumerate.

Georges Ifrah describes the arithmetical state of Europe as late as the 15th and 16th centuries:

A wealthy German merchant, seeking to provide his son with a good business education, consulted a learned man as to which European institution offered the best training. ‘If you only want him to be able to cope with addition and subtraction,’ the expert replied, ‘then any French or German university will do. But if you are intent on your son going on to multiplication and division – assuming that he has sufficient gifts – then you will have to send him to Italy.’

It has to be said that arithmetical operations were not in everyone’s grasp: they constituted an obscure and complex art, the specialist preserve of a privileged caste, whose members had been through a long and rigorous training which had allowed them the mysterious and infinitely complicated use of the classical (Roman) counter-abacus.

A student of those days needed several years of hard work as well as a long voyage to master the intricacies of multiplication and division – something not far short of a Ph.D. curriculum, in today’s terms. The great respect in which such scholars were held provides a measure of the difficulty of the operational techniques. Specialists would take several hours of painstaking work to perform a multiplication that a child could now do in a few minutes. And tradesmen who wanted to know the total of the week’s or the month’s takings were obliged to employ the services of such counting specialists.¹

THE ROMAN NUMERAL SYSTEM

ROMAN NUMERALS WERE USEFUL TO PRE-RENAISSANCE EUROPEANS FOR basic notations, but proved problematic for denoting large numbers. A key issue was the variation in the notation of large numbers. For instance, MM might have been used to express two thousand or a million ($1,000 + 1,000$ or $1,000 \times 1,000$, respectively). Another problem was that the link between the amount of a roman numeral and its length is weak: for example 1,001 can be expressed as MI, but 888, a smaller number, is written DCCCLXXXVIII. Long

1 Ifrah, Georges. 2000.

The Universal History of Numbers from Prehistory to the Invention of Computers. David Bellis, E. F. Harding, Sophie Wood and Ian Monk, translators. New York: Wiley, 577.

2 Guedj, Denis. 1996.

Numbers: The Universal Language. Lory Frankel, translator. New York: Abrams, 49.

3 Ifrah,

The Universal History of Numbers, 588.

4 Menninger, Karl. 1969.

Number Words and Number Symbols: A Cultural History of Numbers. Paul Broneer, translator. Cambridge, MA: M.I.T. Press, 327.

5 Hill, Sir George Francis. 1915.

The development of Arabic numerals in Europe, exhibited in sixty-four tables. London: Oxford UP's Clarendon Press.

strings of characters can be hard to read, making calculations difficult.² (If in doubt about this, try dividing MCXXIV by MCVIX without converting to hindu-arabic numerals first.)

Shifting from written records to a counting table and back to written records was cumbersome and introduced many opportunities for error.

The difficulties involved in working with numbers had effects similar to those of widespread illiteracy. Ifrah notes that prior to the dissemination of the hindu-arabic numerals, “professional arithmeticians, who practiced their art on the abacus, constituted a powerful caste, enjoying the protection of the Church. They were inclined to keep the secrets of their art to themselves; they necessarily saw algorism (the Arabic number system), which brought arithmetic within everyone’s grasp, as a threat to their livelihood.”³

We can only imagine the frustrations of European merchants, who could not even calculate whether they were operating at a profit or a loss, trying to meet the growing demand for silk and spices which they purchased from Indian and Arab merchants – many of whom were, presumably, mathematically adept.

INITIAL DIFFICULTIES

THE HINDU-ARABIC NUMBERS ORIGINATED IN INDIA AROUND THE FIFTH century AD and probably migrated into Arabic cultures through merchant traders in the eighth century. Early introductions of the hindu-arabic numerals into Europe were not successful. Important scholars promoted the system because they had heard it was a superior system that made calculations much easier, but they failed to make use of the system’s key advantage – the zero.

Additionally, the written forms of the numerals themselves proved problematic. Europeans were very inconsistent in the visual orientation of the symbols. During the tenth century, European mathematicians began using the hindu-arabic forms by placing the figures on “apices,” which were markers that were set on counting boards to do calculations. These boards operated like abacuses, in which small disks stand in for the thing being counted. “The rotation, or different orientations, of the individual number symbols and apices may be due to the fact that the counters were customarily placed on the counting board in a particular manner in one monastery and differently in another.”⁴

FIGURE 1

An 11th century multiplication table using arabic and roman numerals, drawn up by a Pater Othlo at the St. Emmeran Monastery at Ratisbon. The first nine symbols reading vertically down the left column are 1 through 9, respectively.

(From Bayerische

Staatsbibliothek, München)

In an 11th century multiplication table from Ratisbon, serifs have been added to the characters, making them looking generally “roman,” but the numerals 1 and 8 alone are familiar to the modern reader (SEE FIGURE 1). Alas, the 9 has been rotated so it looks to us like a 6, and the 6 is squared off, looking more like the letter L. It is hard to see the connection between 2, 3, 4, 5, 7 and our present-day numerals or to their hindu-arabic antecedents.

Some typographic histories give brief mention of the numerals by showing “the style” of numerals in pre-Renaissance Europe. But if we compare the Ratisbon example to those from Hill’s *The development of Arabic numerals in Europe*,⁵ we see that there was in fact no general style at this period, but instead a variety of forms (SEE FIGURE 2).



FIGURE 2

A few early examples of hindu-arabic numerals in Europe, from the work by G. F. Hill. Numeral sources for this figure follow: A. 976 AD, from the manuscript Codex Vigilanus, written in the monastery of Albelda, Spain. Perhaps the form of the 5 is related to the roman numeral “V;” B. c. 1200, from a manuscript; C. c.1350, from an English manuscript; D. probably 1400 to 1450, from an English manuscript; E. 1342, from an astrolabe in the British Museum; F. 1490, from a brass astrolabe; figures stamped; G. 1488, from a woodcut in Augsburg Boethius, German; H. c. 1400, French Astrolabe; I. c. 1400, French or Italian Astrolabe; J. 1400s, Spanish Astrolabe.

Ifrah notes,

Styles obviously varied from one region to another, from one school to another, even from one engraver to another, in a period that had no concept of standardization. Indeed, what we can see happening in these examples is the adaptation of the Ghubar forms of the Arabic numeral to the very different styles of writing practiced in different parts of Europe. So in Italy we see numerals assimilated to the round shapes and wide openings of Italic script, in England to the narrower and more angular shapes of English script, in Germany to the thicker and squarer writing style of German script, and in France and Spain we see them being shaped in harmony with the dominant styles of Carolingian script.⁶

Given the ambiguous orientation of the forms and the fact that standardization was not understood or valued at that time, we can understand why early introductions of this number system were met with skepticism.

In the 12th century, mercantilism and literacy were expanding, and trade and the crusades had increased contact with Arab cultures. Muhammad al’Khuwarizmi’s *Book of Restoration and Equalization* was translated into Latin, thus re-introducing the numerals to Europe. Rather than marks for apices, the numerals, complete with zero, were promoted as a way to solve equations through written calculations. This second introduction of hindu-arabic numerals was roughly

⁶ Ifrah, *The Universal History of Numbers*, 586.

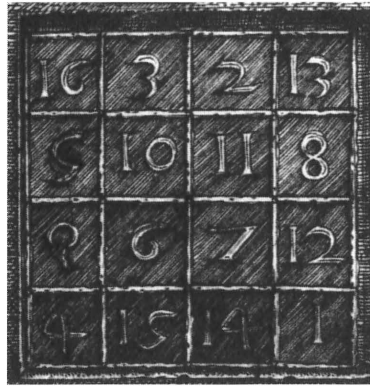


FIGURE 4

From The Carmen de Algorismo of 1240 by the Norman monk Alexander de Villedieu.

(From Hessische Landesbibliothek, Darmstadt)

around the suspicion and confusion about the number zero, for which Europeans had no frame of reference other than its derivation from non-Christian cultures.

Further, there was concern that the new figures could be altered. This is no small point. A letter of the alphabet that is ambiguous in form is usually saved by its context within a word, and that word within a sentence. Numerals however, often lack such clues, and a written inventory might be read as 71 bushels instead of 11, or changed from 33 bushels to 83 bushels without raising suspicions.

European scribes had developed safeguards against the alteration of roman numerals, such as writing all the characters with a single pen-stroke, “like the links in a chain.” The last character in a roman numeral was typically finished in a downstroke rather than an upstroke - the “i” being written as a “j.” Menninger notes a pervasive preference for roman numerals in court documents, and recounts that the City Council of Florence in 1299 made it illegal to write amounts of money in hindu-arabic numerals: “...the old figures alone are used because they cannot be falsified as easily as those of the new art of computation, of which one can with ease make one out of another, such as turning the zero into a 6 or 9, and similarly many others can also be falsified.”⁸

In the 15th Century, there was a third wave of interest in hindu-arabic numerals in Europe, growing out of the growing dependence on mercantilism. Merchants were more focused on the practicality of the new number system than in their suspicions about foreign cultures. Some merchants had traded with the Arabs and Indians who had been using this system for centuries, and they desperately needed

⁸ Menninger, *Number Words and Number Symbols*, 426, 427.

I 2 3 4 5 6 7 8 9 0

FIGURE 5

Adobe® Garamond “Old-style”
numerals from expert set.

to calculate sums in order to run their businesses. Block books and some of the earliest books printed with moveable type were devoted to instruction in using the “new numerals.” Growth in “numeracy” kept pace with the explosion in literacy going on at that time.⁹ Europeans were at last able to calculate with the new numbers, but scribes and typographers had to grapple with a new and essentially foreign set of marks.

ADAPTATION OF FORMS TO WESTERN AESTHETIC

IN ALBRECHT DURER’S ENGRAVING OF 1514, “MELANCHOLIA,” (FIGURE 3) we see hindu-arabic numerals arranged in a magic square. Durer was scientifically minded and a superlative draftsman, yet his numerals of 1514 seem awkward to us today. The stroke widths seem uncontrolled, the 7 is much too wide; the 4 and the 5 both seem off balance. In fact, Durer was attempting to be faithful to the fluid, horizontal strokes of Arabic script and yet squeeze the characters into a grid – literally in terms of the outline of the magic square and more generally in terms of the imaginary grid applied to Western type from the ancient Greek period onwards. In fact, 11 years later Durer wrote *On the Just Shaping of Letters*, diagramming harmonious proportions for letters based on analytical grids.¹⁰

Those who developed letterforms for moveable type shared Durer’s concept of a rigidly oriented grid. They did so in part because it was necessary to the mechanics of typographic composition to draw each character within the space of a rectangular metal block. Although early type looked somewhat like hand-drawn brushstrokes, it was, in fact, created by the carving of metal punches. Through this

9 Menninger,

Number Words and Number Symbols, 334, 335. Menninger describes the Bamberg block-printed book of 1470, a printed Italian textbook of arithmetic of 1478, and a printed German textbook of 1482

devoted exclusively to the new art of written computations with numerals. Menninger observes that the printing press made not only the hindu-arabic numerals, but the counting board more accessible to wide audiences during this period.

“Such text books show not only that computations were made, but also by what methods and how the counting board was set up. These books of computations, which were among the first popular printed works, appeared in large numbers in all countries in the 16th century.”

10 Durer, Albrecht. 1965.

On the Just Shaping of Letters. R. T. Nichol, translator. New York: Dover.

11 Herrick, Earl M. 1999.

"Toward Disambiguating the Term 'Roman.'" *Visible Language* 33.2, 104–126.

12 Haley, Allan. 1995.

Alphabet: The History, Evolution, and Design of Letters We Use Today. New York: Watson-Guptill, 104, 105.

13 Bringhurst, Robert. 1992.

The Elements of Typographic Style. Vancouver: Hartley & Marks, 44, 45, and 221. Bringhurst attributes the popularity of lining figures to the rise of retail trade in the 19th century. According to Bringhurst, old-style numerals are a sign of civilization, in that they keep numerals "on an equal footing with words." Presumably he is referring to how lining figures visually dominate upper and lower-case text, drawing attention to prices.

practice, early type designers were able to bring a level of precision and regularity to new letter and numeral forms that had previously been unachievable. They were able to recreate the "new numbers" in forms consistent with emerging humanist and gothic typefaces by adding serifs, modulating the stroke with vertical or oblique stress and even by creating italic versions of the numerals.

Earl M. Herrick, in a discussion of typography in general, describes a process he calls "Trajanicizing" in which letter forms as diverse as Armenian, Thai and Cherokee have, at various times, been redrawn using a limited set of straight lines and regular curves, given serifs, given vertical or oblique stress and formed into an "upper case" and "lower case" set.¹¹ Ratisbon's example from the 11th century reflects some of these characteristics, notably serifs and regularity of form (FIGURE 1). Impulses toward "Trajanicizing" accelerated as designers recreated forms for the new metal type.

Allan Haley notes that:

*Claude Garamond is generally credited with creating the first typeface whose numerals were specifically designed to reflect the subtleties of its letterforms. Except for a few stylistic variations, Garamond's figures set the standard for numeral design for the next two hundred years. Garamond intended his numerals to be set as part of text copy and designed them to have the same proportions as lowercase letters. Because of this, they do not align with the baseline and the cap line or ascender line of a given typeface, as do the numerals in most fonts today.*¹²

Interestingly, this standardization of hindu-arabic numerals within roman typefaces would seem to be a major achievement, yet is not listed with Garamond's most significant achievements in most references to him.

Today in faces such as Adobe Garamond we have a choice of "old style" numerals with ascenders and descenders and bodies generally as high as lower-case letters, or alternate "lining" figures that align with the capital letters.¹³

In Garamond's old-style numerals the 3, 4, 5, 7 and 9 are configured as descenders and the 6 and 8 as ascenders. Yet one may observe many variations in popular typefaces today, such as 5 as an ascender or all the odd numbers as descenders and the even ones as

ascenders. Given the multiple introductions of the numeral forms into Western writing, it is not surprising that no one configuration is acknowledged as “the original” or as necessarily correct. Each attempt to align them with our alphabet has been subjective and even arbitrary. There is no single instantiation of the numerals that embodies their “real” form in the way that we look to Trajan’s column, rightly or wrongly, as the archetype of our alphabet.

The incorporation of numerals into our expanded alphabet changed the overall visual form of texts. The act of “Trajanicizing” remains incomplete and the numerals, with their Arabic roots, allow the typographer and calligrapher opportunities for sweeping, expressive strokes on an otherwise regimented page.

Some typographers bemoan the current use of lining figures rather than the more graceful old style figures. But American penmanship classes from the 19th century until today have taught students that numerals should be consistent at either the full cap height or half that height. For instance, the Palmer method of penmanship, popular from the 1920s, taught students to write all numerals at a consistent height with very slight descenders on 7 and 9, and the subsequent Zaner-Bloser and recently popular D’Nealian handwriting methods teach children to write all numerals to align exactly.¹⁴ It is not surprising that many designers choose typefaces whose numerals are consistent with how they have been taught to write. Even though ascenders and descenders are supposed to make characters more legible, old-style numerals are unusual enough today that readers may confuse the 0 with the letter “o,” a 9 with a “g,” and so on.

Ironically, two of the figures whose forms changed the least when adapted to our writing system now prove to be the most problematic. The 0 (zero) has long been confused with the letter O, and the 1 (one) with the letter l, but the sudden importance of alphanumeric web addresses, and the computer’s intolerance for misspelling, have made these confusions particularly grievous. Dirk Wendt’s 1969 article “O or 0?”¹⁵ anticipated some of these problems, but they are far from solved.

14 Sassi, Paula A. 1989.

Better handwriting in 30 days: developing a more attractive, readable script for business, school, and personal satisfaction. Los Angeles: J.P. Tarcher; New York: St. Martin’s, 17.

15 Wendt, Dirk. 1969.

“O or 0?” *Visible Language* 3.3, 241–48.

16 Diringer, David. 1968.

The Alphabet: a Key to the History of Mankind. 3rd ed., vol. 1. New York: Funk & Wagnalls, 13.

17 DeVinne, Theodore Low. 1969.

The Invention of Printing. [1876] Detroit: Gale Research Co., 116–118.

FINITE AND FLEXIBLE

THE NUMERAL SYSTEM THAT THE ARABS ADOPTED FROM INDIA WAS AN enormous improvement upon roman numerals and the many other systems Europeans had used for counting and calculating prior to the 13th century. This was because of the system's elegance: all possible numbers can be expressed with just ten symbols. As in the Western alphabet, there is an efficiency and economy of means effected by recombination of just a few constituent parts.

Many accounts of the history of typography mention the superiority of phonetically-based alphabets over ideographic writing systems, noting how much easier it is to learn the 26 symbols in our alphabet than the 9,000 to 80,000 used in Chinese. David Diringer effuses:

The alphabet is the last, the most highly developed, the most convenient and the most easily adaptable system of writing. Alphabetic writing is now universally employed by civilized peoples; its use is acquired in childhood with ease. There is an enormous advantage, obviously, in the use of letters which represent single sounds rather than ideas or syllables. No sinologist knows all the 80,000 or so Chinese symbols, but it is also far from easy to master the 9,000 or so symbols actually employed by Chinese scholars. How far simpler is it to use 22 or 24 or 26 signs only! ... Thanks to the simplicity of the alphabet, writing has become very common; it is no longer a more or less exclusive domain of the priestly or other privileged classes, as it was in Egypt, or Mesopotamia, or China.¹⁶

The limited number of characters used in the Western alphabet is often cited as creating the perfect setting for the birth of typography in Europe, as well. For instance, De Vinne notes that moveable type was invented by the Chinese and Koreans earlier than by Gutenberg, but moveable type was not widely used in those cultures for centuries because it would have involved casting too many characters.¹⁷

Our alphabet has benefited by reduction to just a few different letters but similarly by the simplification of its visual forms into those made with just a few strokes. The Greeks and Romans adapted the Phoenician alphabet by reducing it to regular marks of uniform proportions. These limited constituent shapes (lines, curves, verticals, horizontals and serifs) are combined and recombined to create all the letter forms in the alphabet – each letter easily

distinguished from the next yet together forming a visually unified whole.¹⁸ The introduction of the hindu-arabic numeral system, based on the infinite recombination of a few component symbols, fit in with an emerging European worldview in which all things could be built from, or broken down into, repeatable parts. Ironically, despite the “Trajanizing” mentioned earlier, calligraphers and type designers still struggle to visually incorporate hindu-arabic numerals into this limited system of marks. According to calligrapher Jacqueline Svaren, “The numerals are surprisingly difficult [to render]. This is due, in part at least, to the subtle differences between the well-made figures & those we have done incorrectly for so long. Another reason is the basic difference in rhythm. These symbols are not Western – as are our letterforms. Rather, they are Eastern, from India, via Arabia.”¹⁹

INTERRELATIONSHIP BETWEEN LETTERS AND NUMERALS

THE NUMERALS ENTERED OUR CULTURE OVER A PERIOD OF TIME THAT coincided with complex intellectual upheavals in Europe. The upswings in mercantilism, travel, paper production, literacy, mass production of texts and tolerance of “non-Christian” ideas all played parts in making the numerals both accessible and necessary. It was a time when printed books, block books and manuscripts existed side by side and when gothic and humanist letters were written on the same page. At roughly the time Gutenberg’s press was putting scribes out of business, hindu-arabic numerals were being disseminated across Europe through the printed books that Gutenberg spawned.

As book publishing grew, numerals made the organization of texts more clear, enabling bible verses to be located, legal codes to be made uniform and conflicting texts to be reconciled. Eisenstein notes, “The use of arabic numbers for pagination suggests how the most inconspicuous innovation could have weighty consequences – in this case, more accurate indexing, annotation and cross-referencing resulted.”²⁰ In short, conventional “literacy” was enhanced in a variety of ways by readers’ familiarity with hindu-arabic numerals.

The broad impact of hindu-arabic numerals was that they gave Europeans a much greater ability to manipulate numbers, which

18 Carter, Rob, Ben Day, Phillip B. Meggs. 1993.

Typographic Design: Form and Communication 2nd ed. New York: Van Nostrand Reinhold, 30, 31. “Letterform combinations from the Times Roman Bold font demonstrate visual similarities that bring wholeness to typography. Letterforms share similar parts. A repetition of curves, verticals, horizontals, and serifs are combined to bring variety and unity to typographic designs using this typeface. All well-designed fonts of type display this principle of repetition with the variety that is found in Times Roman Bold.”

19 Svaren, Jacqueline. 1975.

Written Letters: 22 Alphabets for Calligraphers. Freeport, ME: Bond Wheelwright Co., 45.

20 Eisenstein, Elizabeth. 1979.

The Printing Press as an Agent of Change, vol. 1. Cambridge: Cambridge University Press, 106.

21 McLuhan, Herbert Marshall. 1962.
*The Gutenberg Galaxy: The Making of Typographic
Man*. Toronto: University of Toronto Press.

in turn helped to propel Western culture toward its ever-growing preoccupation with written data. This shift from haptic and oral traditions to a fixed scribal activity described by Marshall McLuhan in *The Gutenberg Galaxy*²¹ had an important numerical component. Europeans' tendency to "think on paper" depended, in part, on becoming comfortable with writing, as well as calculating with the numerals.

In short, the introduction of hindu-arabic numerals enabled Europeans to make calculations but also made the culture more "graphical." Europeans had to overcome their ignorance and prejudice toward a foreign number system and their confusion about how to write and print hindu-arabic numerals in order to incorporate these characters into their overall writing system. While the numerals we use today remain residually "foreign" in some ways, their incorporation into our writing system is a significant part of the history of Western typography.

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AUTHOR NOTE

LIZ C. THROOP, an Assistant Professor in Graphic Design at Georgia State University, has practiced print, signage and packaging design in Atlanta. She received her Masters in Graphic Design from North Carolina State University and has taught at Atlanta College of Art and Georgia State. Throop is currently researching design assessment and social class.



