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ITALIAN *ZERO*: A COMPARATIVE HISTORY

Abstract: The aim of this paper is to provide the first comparative, corpus-based description of the linguistic history of the Italian numeral-word *zero*. We show that the formal and semantic development of *zero* is far more complex than has been assumed and that it is intertwined with the history of *cifra*, originally a medieval Latin name for the symbol ›0‹. *Cifra* has received little attention from linguists despite the fact that its semantic development as a polysemous word is still reflected in modern Italian and in some of the other languages here explored. We examine the occurrence of these words in the context in which numerals for the symbol ›0‹ originated, namely the mathematical register, and then consider their uses in non-mathematical sources. We employ diachronic and synchronic analysis, both intragenre (within mathematical writings) and intergenre, and provide a comparative perspective by placing side-by-side works written in a variety of languages which have so far only been studied separately. Our theoretical observations and arguments cover both semantics and morphology. We argue that *cifra* underwent productive word-formation processes which created new lexemes via derivation and that its semantic development is a kind of expansive synecdoche. We also set out the challenges encountered in trying to explain the form *zero*.

Keywords: *zero*; *cifra*; Roman numerals; Indo-Arabic numerals; arithmetic manuals; Italian vernacular; European vernaculars

1. Introduction

Buck (1949: 936) voiced a commonly held opinion when he stated, for Indo-European languages, that: »No class of words, not even those denoting family relationship, has been so persistent as the numerals in retaining the inherited words. Except for some suffix-variation and actual substitution in the case of ›one‹ (13.32), the IE words for ›one‹ to ›ten‹ have persisted everywhere with only slight changes other than phonetic; likewise the IE word for ›hundred‹, while for ›thousand‹ there are several different groups«. From a linguistic perspective, numerals are instantiations, the linguistic representatives, of numbers:[1] ›1‹ is a cardinal number, its cardinal numeral is English *one,* French *un*,

[1] In mathematics, an arithmetical ›numeral‹ is a symbol that stands for a number. While from a linguistic perspective ›one‹ is the numeral of the cardinal number 1, from a mathematical perspective the symbol 1 is a ›numeral‹ standing for a quantity, a distinct arithmetical value. We speak, in fact, of Roman numerals, Indo-Arabic numerals, and so forth. Chrisomalis (2010) distinguishes between ›numeral-words‹ (›one‹, ›two‹, etc) and ›numeral-signs‹ (›1‹, ›2‹, etc).

Romanian *unu*, Russian *odin*, Latin *unus,* Greek ἑνα, Sanskrit *eka,* and so forth.[2] When compared to the history of other numerals, the appearance of a term for the numeral-sign ›0‹ is a recent phenomenon, and is intimately tied up with the transmission of the Indo-Arabic decimal numeration system. With the introduction into the West of Indo-Arabic figures (›0‹, ›1‹, ›2‹, ›3‹, and so forth), medieval Latin employed several numeral-words to denote the symbol ›0‹ and its arithmetical value. Between the late thirteenth and fifteenth centuries, these spread unevenly across Europe and were vernacularized; some eventually fell into disuse, while others underwent semantic innovations.

In modern Romance languages, the numeral for ›0‹ is, for example, Italian *zero*, Spanish *cero,* French *zéro*, Portuguese *zero*, Romanian *zero*.[3] Etymological dictionaries and historical studies unanimously say that the ultimate origin of the numeral *zero* is Arabic *ṣifr,* which literally meant ›empty‹ but came to denote ›zero‹. The etymology and semantic development of *zero* has hitherto been sketched only very roughly, and we lack a study which takes into account corpus-based evidence.[4] The history of *zero* is commonly given as: Arabic *ṣifr* > medieval Latin *zephyrum* > Italian *zero,* French *zero*, and Spanish *cero*. We contend that the history of *zero* is far more complex than has been assumed and that it is intertwined with the history of *cifra,* a medieval Latin name for the symbol ›0‹ which has received little attention from linguists notwithstanding its interesting semantic development as a polysemous word, still reflected in modern Italian and in some of the languages here explored.

Zero and *cifra* have commonly been assigned the same origin: Arabic *ṣifr*.[5] We provide a descriptive corpus-based account of their history; we set out new facts, and in doing so, we give the first attempt to solve or at least identify the problems in reconstructing the history of these terms. We employ diachronic and synchronic analysis, both intragenre (within mathematical writings) and intergenre (outside mathematical writings), and provide a comparative perspective by placing side-by-side works written in a variety of languages so far studied separately.[6] This

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[2] All translations are our own unless otherwise stated. The research for this paper has been funded by the Leverhulme Trust through the award of a Research Grant Project (RPG-2021–122) at the Faculty of Linguistics, Philology, and Phonetics of the University of Oxford.

[3] Systematic syntheses and linguistic reconstructions of Indo-European numerals can be found, among others, in Meier-Brügger (2003: 231–236) and Mallory and Adams (2006: 311–320). Szemerényi (1960) and Gvozdanović (2011) offer a broad perspective on Indo-European numerals in various languages.

[4] A brief, and in some respects outdated, study on the word *zero* is found in Boncompagni (1883). For the treatment by Jordan (1905), see section 3.2.

[5] Stanley (2004: 163) observes: »how to get from Arabic sifr to French zéro (and Italian zero), whence English zero, is no laughing matter. The phonological development to cipher is relatively easy, but the semantic development of cipher is not.« See also Wartburg (1922: 156–158).

[6] The mathematical literature contains the earliest and most numerous instances of numeral-words for ›0‹, thereby allowing a comparative diachronic and

methodology allows us to throw new light on the history of these terms while also revising some outdated etymological dictionary entries. Our historical corpus consists of mathematical texts written in Italo-Romance dialects, medieval Latin, Ibero-Romance, French, English, German, and Dutch, and spanning around four centuries (1200–1600 CE); passages from non-mathematical sources such as literary works and texts from other technical registers are also provided.[7] In addition, we have taken material examples from historical dictionaries to examine the historical developments of numeral-words for ›0‹. In reconstructing the linguistic history of *zero*, we begin with the complex dynamics which led to the adoption and adaptation of Indo-Arabic numerals in the West. Their transmission and adoption via Arabic sources stimulated the beginning of new mathematical writings, first in Latin and then in the vernacular languages, across Europe.[8] Roman numeral-signs did not follow a place-value system and had no symbol (or word) corresponding to our ›0‹; the transition from Roman to Indo-Arabic figures embodies a true paradigm-shift in the history of mathematical thought and practice, and it is one which has considerable implications for the language of mathematical expressions.

The semantic development of the numeral-words denoting the number ›0‹, which we demonstrate to have been adopted in a non-uniform way across European languages reflecting the uneven circulation of mathematical works, has followed different patterns in different languages. Our observations cover both semantics and morphology. We argue that the semantic development of *cifra* is a kind of expansive synecdoche, and provide evidence that this term, once it had entered European vernaculars as a neologism, illustrates a process of dynamic and productive lexicalization.[9] Latin *cifra* developed in a time when the vernaculars were increasingly being used as media of formal and technical writing; once adapted into the various European vernaculars, *cifra*, in origin a Latin numeral-word for the symbol ›0‹, both yielded new lexemes via derivational processes and underwent semantic expansion.

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synchronic analysis. It is beyond the scope of this paper to discuss the complete history of Indo-Arabic numerals in the West; two classics on the history of Indo-Arabic numerals are by Smith and Karpinski (1911) and Cajori (1929). On medieval Latin mathematics, see Folkerts and Hughes (2016: 4–223). As explained by Chrisomalis (2010), in Europe Roman numerals were for a long time used side by side with the newly introduced Indo-Arabic figures.

[7] We have drawn on all the sources currently available to us; sources are quoted chronologically.

[8] We use the expression ›Indo-Arabic numerals‹ to refer to the symbols ›1‹, ›2‹, ›3‹ and so forth, meaning that, as explained in footnote 1, in this expression we employ the term ›numeral‹ from a mathematical perspective to denote Indo-Arabic ›numeral-signs‹, ›symbols‹.

[9] For our purposes we follow Bussmann's definition of lexicalization: »the adoption of a word into the lexicon of a language as a usual formation that is stored in the lexicon and can be recalled from there for use« (1996: 279)

As for Italian *zero*, besides providing evidence of its history and diffusion in Italy and beyond, we critically review some suggested linguistic reconstructions and highlight the problems they present.

2. Indo-Arabic Figures in the West: New Knowledge, New Textual Traditions

In modern scholarship Western numeral-signs, that is to say the digits commonly used across the globe (›0‹, ›1‹, ›2‹, ›3‹, etc.), are often referred to as ›Arabic numerals‹ or ›Indo-Arabic numerals‹.[10] Western numerals are, in fact, an adaptation of Arabic numerals based upon Indian digits. The Indo-Arabic numeral system adopted universally across the globe is the most common system for the symbolic representation of numbers; it follows a ciphered-positional numerical notation and is based upon the system of decimal numeration that originated in India and was transmitted to the West via the translation of Arabic sources into Latin. In late medieval and early Renaissance Europe, the transition process from Roman (I, II, III, etc.) to Indo-Arabic figures represented a fundamental change on cultural, social, mathematical, and linguistic levels which produced new knowledge and stimulated the beginning of new genres of mathematical writing, whose aim was to teach positional numeration and mathematical procedures based on decimal arithmetic.[11]

The Arabs learned Indian mathematics through trade and the occupation of northern regions of the Indian subcontinent.[12] The Indian ›0‹ (often represented as a dot or a small circle) was a new symbol for the Arabs, requiring the coinage of a new term;[13] the Arabic term which came to denote ›zero‹ is the adjective *ṣifr*, literally meaning ›empty‹, a semantic calque from the Sanskrit adjective *śūnya* ›empty, void‹. In mathematics, this adjective was used as a noun: in the Sanskrit mathematical lexicon, *śūnya* is a term to denote the digit ›zero‹, it is thus a technical term and numeral-word for ›0‹.[14] Within the mathematical register, the Arabic adjective *ṣifr* underwent the same process, becoming a numeral-word for ›zero‹. It seems that the earliest known medieval Arabic works elucidating Indian arithmetic and algebra are those by al-Khwārizmī (ninth century CE), a renowned Persian polymath who wrote

[10] On numerals and arithmetic in the Middle Ages, see Burnett (2010).
[11] Modern authors have often argued that the new numerals faced considerable opposition from the authorities, but Nothaft (2020) demonstrates these arguments to be unproved.
[12] On the history of mathematics in India see Plofker (2009); a classic is by Datta and Singh (1962 [1935]). Science in early and medieval Islam has been extensively covered; see, for instance, Berggren (2016 [1986]).
[13] Before adopting the Indian numerals, one of the most common numerical notations used among the Arabs was the *abjad* numerical system (of pre-Islamic origin), in which the letters of the Arabic alphabet are assigned numerical values.
[14] Other terms for ›zero‹ are synonyms of ›sky‹ and ›space‹, such as *kha, viyat,* and *nabha*.

numerous treatises on mathematics, astronomy, and geography. The Indian symbolic notation to represent numbers was taken over by Syrian and Arabic writers and eventually passed to Western Europeans through the translation of mathematical works from Arabic into Latin by twelfth century scholars such as Gerard of Cremona, Adelard of Bath, Robert of Chester, and Plato of Tivoli.[15]

By the end of the tenth century CE, Indo-Arabic figures had made their appearance in Western Europe but had no representation of decimal values.[16] As for mathematical writings focusing on the practice of mathematics, before the spread of Indo-Arabic numerals treatises on the reckoning device called ›abacus‹ enjoyed two centuries of predominance in the educational world of the Latin West. Manuscript evidence indicates that in the eleventh century Indo-Arabic numerals were being employed to mark the abacus counters but did not yet represent place-values; the numerals became well-known in monastic schools. [17]

Written arithmetic based on the Indo-Arabic numeral system entered Latin Europe in the first half of the twelfth century as part of a wave of translations of Arabic scientific works. Italy and Spain were home to multilingual centres of knowledge-production and learning: in Spain, for instance, the Toledo School of translators, a group of scholars active during the twelfth and thirteenth centuries, played a crucial role in the transmission of Arabic science. The impact of the translation movement was enormous; the vast corpus of Arabic mathematical works which was made available to Latin readers revolutionized Western mathematical culture. Authors had to adapt their language to meet the challenges posed by changes in knowledge and practice. The introduction of Indo-Arabic numerals, and the major breakthrough in scientific and cultural practices they engendered, coincided with treatises employing the noun *algorismus*, a neologism which is the Latin adaptation of the personal name al-Khwārizmī. The earliest known work on Indian arithmetic (known through its Latin translations) is by al-Khwārizmī', this text is no longer extant in Arabic but is preserved only in four partial Latin translations dating from the twelfth to the thirteenth century: the *Dixit algorismi,* the *Liber ysagogarum alchorismi*, the *Liber alchorismi*, and the *Liber pulueris* are precious pieces of evidence of the birth of

[15] The mathematics of Latin Europe was taught within the framework of the seven liberal arts. The most important book on theoretical mathematics throughout Latin Christian Europe is Boethius' *De institutione arithmetica*. See Grant (1974) and Folkerts and Hughes (2016). On translations of Arabic mathematical texts in Latin Europe, see Burnett (2001).

[16] The oldest known examples of the nine symbols are in the *Codex Vigilanus* (976 CE) and the *Codex Emilianus* (992 CE), two Latin manuscripts written in monasteries in northern Spain.

[17] Gerbert of Aurillac (ca. 945–1003 CE), who served as scholasticus of the cathedral school of Rheims, is a seminal figure in the intellectual life of tenth century Latin West. When still a student, Gerbert spent three years studying in Spain and was exposed to Arabic science.

positional numeration in the West.[18] Several *algorismi* were written at the time and during the following century: a French *algorismus* (ca. 1275), the so-called Hannover *algorismus* (thirteenth century), and an early fourteenth century Old Norse *algorismus,* just to mention some.[19]

The term *algorismus* came to denote the art of computing by means of the new decimal number system and Indo-Arabic figures, and one of the earliest works to employ this term is the *Liber abaci* of Leonardo Pisano (also known as ›Fibonacci‹) which, however, given his presentation style and the topics covered, does not belong to the *algorismi* tradition. Written in Latin, the *Liber abaci* (first redaction 1202, second 1228) is the earliest surviving work to teach the methods of computation using Indian positional numeration.[20] This is an encyclopaedic work comprising fifteen chapters on arithmetic, algebra, and geometry which include a wide variety of sample problems. It is also the first Latin work to provide a large section on business mathematics involving financial transactions, money exchange, barter, and other trade-related practices. Leonardo is the first to employ the term *abacus* to refer not to the counting board but to the art of performing calculations using Indo-Arabic numerals. In the preface, Leonardo states how in his studies he has found the Indian number system and its methods of calculation to be superior to all other methods. He explicitly mentions the ›Indian figures‹ (*novem figure indorum*) and that in Arabic the sign ›0‹ is called *zephyrum*. This is the earliest occurrence of a Latin term for the symbol ›0‹. Clearly, *zephyrum* is not actually an Arabic word, and Leonardo seems to be operating a sophisticated kind of folk etymology, namely a phonological adaption into a familiar Latin guise of the Arabic word *ṣifr* ›empty‹.[21] The following sections will show that that most later authors across Europe, writing in both Latin and the vernacular, say that *zephyrum* or the corresponding vernacular form of the term is an Arabic word or of Arabic origin, clearly relying on Leonardo (see *quod arabice zephirum appellatur*) either directly or indirectly through secondary sources.

In Europe the most influential *algorismi* were the prose-style *Carmen de Algorismo* (ca. 1220 CE) by the French scholar-monk Alexander de Villedieu, and *Algorismus vulgaris* (ca. 1240 CE) by John

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[18] These *algorismi*, whose authorship remains uncertain, are considered the first surviving Latin versions of Arabic works expounding place-value notation based on Indo-Arabic figures. They elucidate new procedures of calculation and, in doing so, mark a significant departure from the traditional methods of the abacus.

[19] For a more detailed list of *algorismi,* readers can refer to Smith and Karpinski (1911), Benedict (1916), and Allard (1991).

[20] Among the Arabisms found in this work is *algebra*. Early Italian vocabulary included numerous Arabisms spread across most semantic fields. The incorporation of Arabisms first into Latin and then into Romance vocabulary posed considerable problems of phonological adaptation.

[21] On folk etymology as the substitution of an alien and impenetrable term by a form (or forms) that is phonologically similar to it and also familiar to speakers, see Maiden (2008).

of Sacrobosco.[22] Both Villadei and Sacrobosco were trivial and quadrivial authors whose works were standard university textbooks. The aim of these texts—which unlike the *Liber abaci* were concise (intended to be memorized) and lacked sample problems and any reference to business arithmetic—was to teach the new numerals and the methods of computation based on them. Both works were part of the university teaching curriculum at various locations in Europe, for instance at Oxford and Paris. The *Algorismus vulgaris* and, to a slightly lesser extent, the *Carmen de Algorismo* were extremely influential works which, as we will show, also played a major role in shaping part of mathematical lexicon in several European languages. The significant number of surviving manuscripts of both works attest to their popularity and wide circulation.[23] The *Algorismus vulgaris* by Sacrobosco was the first Latin work which taught decimal arithmetic by means of Indo-Arabic numerals to be widely adopted in universities; it was one of the most popular Latin textbooks on arithmetic of the Middle Ages and remained the standard university text for several centuries.

A different type of mathematical writing—in scope, language, authorship, and readership— started developing in Italy in the late thirteenth century: up to the sixteenth century the mathematical scene in Italy is dominated by so-called *abbaco* texts, training manuals produced in large numbers during the Renaissance in the most dynamic cities of the Italian peninsula.[24] The *abbaci* played a major part in teaching new mathematical knowledge based on Indo-Arabic figures and business practices in order to train future merchants, bankers, and artisans. Their purpose was to put mathematical knowledge into everyday use. The term *abbaco* employed to mean ›computation‹ by means of the Indo-Arabic numerals continues the very meaning attributed to term *abacus* in the *Liber abaci*. *Abbaci* were written in Florentine and other Romance dialects of Italy— a fact which underlines the popular audience that they addressed. The fourteenth and fifteenth centuries are the golden age of *abbaco* manuals. *Abbaci* were produced in extremely large numbers, the first being printed in 1478.[25]

Outside Italy, the earliest surviving textbooks on decimal arithmetic (some with a more practical emphasis than others) are from late fourteenth century Spain, followed by texts produced in the fifteenth century in France and Germany. Germany had a remarkable tradition of practical arithmetic texts called *Rechenbücher* produced in large

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[22] Little is known about John of Sacrobosco apart from his writings and that he taught at the University of Paris from ca. 1230 until his death in ca. 1256. He was an author on quadrivial subjects and wrote seminal works which became standard texts for astronomy and mathematics students throughout Europe up to the sixteenth century. On Villadei, see Ambrosetti (2016).

[23] The Bodleian Library in Oxford alone holds almost 30 manuscripts of the *Carmen de algorismo* and *Algorismus vulgaris*.

[24] Van Egmond (1980) observes that there are more than 400 surviving *abbaci*, both in manuscript forms and early printed works.

[25] The first printed arithmetic text was the anonymous *Arte dell' abbaco,* published in 1478; Swetz (1987) translates the complete work.

numbers during the sixteenth century. Among latecomers are the Low Countries, with a growing production of works in Antwerp, and also Prague and Kraków. As for England, the oldest surviving complete practical arithmetic text was published in 1536. The importance of the printing press in the diffusion of mathematical textbooks and the standardization of their format, content, and lexicon is undeniable. Danna (2021) has shown that the largest number of mathematical works on positional numeration and arithmetic produced between 1285 and 1595 were in Italian, German, and Latin, with Germany surpassing the Italian production in the sixteenth century.

In what follows we will demonstrate that language contact, manuscript circulation, and the printing revolution were all factors enabling the *Algorismus vulgaris* and the *Carmen de Algorismo* to play an evolving role which extended beyond the Latin-using intellectual circles.

3. Corpus-Based Comparative Analysis

3.1 Evidence in Latin

The earliest attestations of numeral-words used in Latin to name the symbol ›0‹ are found in the following late twelfth to early thirteenth century works: [26]

term	**where attested**
circulus	*Dixit algorizmi,* [27] *Liber ysagogarum alchorismi,* [28] *Liber alchorismi,* and *Liber algorismi de pratica arismetrice* [29]
ciffre	*Liber ysagogarum alchorismi*
cyfre	*Ocreatus helceph*
nihil/nichil	*Liber ysagogarum alchorismi, Tractatus algorismi, Liber pulueris,* [30] *Intencio algarismi,*[31] and *Algorismus vulgaris*
theca	*Algorismus vulgaris*

[26] Latin medieval mathematical terminology is investigated by Allard (1990: 137–181; see particularly, p 147, 154, 166, and 176).
[27] Also known as *Algoritmi de numero Indorum*. The Latin text based on MS Ii.VI.5 (Cambridge University Library) is available in Boncompagni (1857). English translation and analysis by Crossley and Henry (1990: 130–131) and Folkerts (1997). See also the analysis in Folkerts (2001: 13–38).
[28] It has been tentatively attributed to Adelard of Bath and Petrus Alfonsus.
[29] By Ioannis Hispalensis. *Joannis Hispalensis liber algorismi de pratica arismetrice* is published in the second part of Boncompagni (1857).
[30] See Vogel (1963).
[31] See Karpinski (1921).

cifra *Carmen algorismo* and *Algorismus vulgaris*.[32]

These terms, which we discuss in more detail later, may be classified into three semantic categories: 1) terms referring to the value of zero, such as *nihil* or *nichil*; 2) terms denoting the shape of the symbol, such as *circulus* and *theca*; 3) the numeral-word resulting from the Latin adaptation of Arabic *ṣifr,* which is *cifra* (or variant spellings *ciffre, cyfra,* and *cyfre*).[33]

In the *Algorismus vulgaris,* Sacrobosco provides four terms to denote ›zero‹: *circulus, theca, figura nihili,* and *cifra,* but it is the last-named that is mostly used by the author. Villadei was French and uses the Latin term *cifra*. Leonardo was Italian and coined the term *zephyrum* (it appears for the first time in his *Liber abaci*). As the following sections will demonstrate, it is significant that *chifre/chiffre* was mostly used in French vernacular works (but would eventually undergo a semantic specialization, being replaced by *zero*), whereas forms of *zero* became the dominant term in the Italian vernaculars.

At the very beginning of the *Liber abaci*, one finds the neologism *zephyrum* to denote ›zero‹:

> Novem figure indorum he sunt: 9 8 7 6 5 4 3 2 1. Cum his itaque novem figuris et cum hoc signo 0 quod arabice zephyrum appellatur scribitur quilibet numerus ut inferius demonstratur (Boncompagni 1857: 2).

> »The nine Indian figures are: 9 8 7 6 5 4 3 2 1. With these nine figures and the sign 0, which in Arabic is called *zephyrum,* any number whatsoever is written, as demonstrated below«.

Leonardo employs *figura* to denote the numeral-signs representing the nine Indian figures. *Figura* is the term commonly used in *algorismi* to denote ›figure, digit‹, while in the earlier tenth century tradition of abacus literature, that is to say in the manuals teaching the use of the reckoning device, the terms used are *litera* and *caracter*. [34] We should keep in mind that before the introduction of Indo-Arabic numerals, the numeration system was based on Roman numerals, which used the letters of Latin alphabet; *litera, forma, nota,* and *caracter* were the terms used to indicate a Roman numeral. Notably, the term *figura,* occurring

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[32] Greek τζίφρα is used, for instance, in Maximus Planudes' twelfth century work on arithmetic *Psephophoria kat'Indous*, edited and translated into French by Allard (1981).

[33] The Jewish scholar Rabbi ben Ezra (1092–1168), who lived in Muslim Spain, used both *sifra* and *galgal* (the Hebrew word for ›wheel‹); see Smith and Karpinski (1911: fn 233).

[34] Richer of Reims (tenth century) credited Gerbert with having introduced the use of the *formae* or *notae*, denoting the nine numeral signs (excluding zero) initially used on counting boards, replacing a large number of tokens placed in any column with a single token bearing one of these signs. These marked tokens, called ›apices‹, were used as a teaching tool between the tenth and twelfth centuries; see Evans 1977. No zero-sign was needed because counting boards are positional by their nature, without the need for a placeholder.

in medieval *algorismi* to refer to one of the nine Indo-Arabic digits continued the use found in earlier treatises on the abacus.[35]

The following definition and explanation of the workings of ›0‹ as a digit and placeholder found in Sacrobosco's *Algorismus vulgaris* were copied or rephrased in arithmetic manuals throughout Europe up to 1600 (see further below):

> Decima figura dicitur theca, vel circulus, vel cifra, vel figura nihili quia nihil significat, sed locum tenens dat aliis significare: nam sine cifra vel cifris purus non potest scribi articulus (Halliwell-Phillipps 1839: 2).

> »The tenth figure is called *theca*, circle (*circulus*), cipher (*cifra*), or the figure of nothing because it signifies nothing (*nihil*). But it makes others to signify because it holds a place, in fact without a cipher or ciphers a pure article cannot be written«

Sacrobosco is not saying that the figure ›0‹ does not stand for anything; here he is making it clear that the ›0‹ is called the ›figure of nothing‹ because, numerically, it stands for ›nothing‹, and is thus to be considered as having a value of ›nothing‹, just as 1 (the cardinal number) stands for the numerical value ›one‹ (its corresponding numeral) , 2 for the value ›two‹, etc. In brief, ›nothing‹ is the numerical value of the symbol ›0‹; it is called the figure of ›nothing‹ by virtue of the fact that it stands for ›nothing‹. Sacrobosco also specifies that ›0‹ is a placeholder and in this role it changes the value of other numbers, such as in this case of an »article« which cannot be formulated without ›0‹.[36] This explanation was to be copied and rephrased widely by most of the later authors of vernacular practical arithmetic manuals in Europe for several centuries.

Cajori (1929: 51) observes that *theca*—of which Sacrobosco provides one of the earliest, if not the earliest, examples of such a usage—explains the way ›0‹ was represented in eleventh-century astronomical manuscripts, that is to say by means of letters of the Greek alphabet. Halliwell-Phillipps (1839: fn6) observes that, in some manuscripts containing Sacrobosco's work, *theca* appears as *theta*: in this regard, one might note the visual relationship between the term *theca,* denoting a symbol having a circular form, and circular shape of *theta,* the letter of the Greek alphabet. The thirteenth century Danish astronomer and mathematician Petrus de Dacia, commenting upon Sacrobosco's *Algorismus vulgaris,* explains that *theca* is named after a circular branding iron called *teca* (»quia rotunda est, dicitur haec figura teca ad similitudineam tecae. Teca enim est ferrum figurae rotundae […]«), and also says that *circulus* is given because of the shape of zero (»haec etiam

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[35] See, for instance, such usage in the eleventh century *De calculatione* by Pandulf of Capua, a Benedictine monk of the abbey of Monte Cassino (in southern Italy); this work is investigated in Gibson and Newton (1995).

[36] Latin *articulus* (literally (»joint / knuckle«) was the Latin term to denote the tens (10, 20, 30, etc.), *digitus* (literally »finger«) was the name for »digit«. The semantics of these terms derive from finger-reckoning: here the distinction is between two-digits and single-digit numbers.

figura dicitur circulus quia est figura circularis«). Moreover, Petrus gives an interesting explanation of the semantics of the word *cifra,* which he seems also to connect with the circular form of the symbol it denotes: »vocatur etiam cyfra, quasi circumfacta vel circumferenda, quod item est, quod circulus hoc habito respectu ad centrum«.

Together with Sacrobosco's, the other most influential *algorismus* was the *Carmen de algorismo* (early 1200 CE) by Villadei, which begins with:

> Haec algorismus ars praesens dicitur in una | talibus Indorum fruimur bis quinque figuris |
> 0. 9. 8. 7. 6. 5. 4. 3. 2. 1. | Primaque significat unum duo vero secunda | Tertia significat tria sic procede sinistra | Donec ad extremam venias quae cifra vocatur | Quae nil significat dat significare sequenti | Quaelibet illarum si primo limite ponas | Simpliciter se significat: si vero secundo | Si decies: sursum procedas multiplicando (Halliwell-Phillipps 1839: 73–74).

> »This present art is called *algorismus*, in which we make use of ten Indian figures:
> 0. 9. 8. 7. 6. 5. 4. 3. 2. 1. The first (figure) signifies one, two the second, three the third: thus proceed left until you come to the end which is called *cifra*, which signifies nothing. It gives significance to what is behind it. If you put any of these (figures) in the first place, it signifies simply itself; if in the second, itself tenfold: multiplying (in this very way) you should proceed further«.

Alongside the rise of vernacular literature, mathematical texts in Latin continued to be written by humanists, intellectuals, and philosophers, and to be studied by educated readers and university students as part of the *quadrivium*. Two important processes took place in tandem: the rise of university education forming a growing number of educated readers, and the rise of vernacular literature on subjects including mathematics among a growing public of amateurs, professionals, and the common people. A quick analysis of some of the terms and definitions used in early printed mathematical manuals written in Latin and several European vernacular languages shows the determining role played in shaping the mathematical lexicon across space and time by Leonardo Pisano's Latin *Liber abaci* and the *algorismi* by Sacrobosco and Villadei. It should be borne in mind that Latin texts were certainly more mobile and thus easily accessible (to learnèd audiences) than vernacular ones. Manuscript circulation, the printing revolution, and both trade book and knowledge networks were crucial factors contributing to the standardization of manuals and lexicon.

An unpublished manuscript in Latin from ca. 1325 uses *nichil* and *cifra* for ›zero‹.[37] In Girolamo Cardano's *Practica arithmeticae et misurandi singularis* (first published in 1539) the term for ›zero‹ is *nihil*. In *Logistica, quae et arithmetica vulgo dicitur* (edition published in 1559) the Spaniard Joannes Buteo says that *zero* is an Arabic word: »[…]

[37] Housed in Florence, National Library, MS Conv. Sopp. C.7. 2645 see folio 1.

cui nomen est Arabice zero«.[38] In *Arithmetica,* printed by André Wechel (died 1581 CE), one reads: »circulus, quae nota est ultima, nil per se significat«.[39] Smith and Karpinski (1911, chap. 4) emphasize that earlier historians made numerous guesses as to the origin of the word *cifra*. For instance, in *De numeratione emendata, veteribus Latinis et Graecis visitata* (published in 1582) the German professor of Greek Matthaeus Hostus states:

> Siphra vox Hebræam originem sapit refértque: & ut docti arbitrantur, à verbo saphar, quod Ordine numerauit significat. Unde Sephar numerus est: hinc Siphra (vulgo corruptius). Etsi verò gens Iudaica his notis, quæ hodie Siphræ vocantur, usa non fuit: mansit tamen rei appellatio apud multas gentes (Smith and Karpinski 1911: fn 211).[40]

In *Arithmetica practica* (edition published in 1544) by the French mathematician Oronce Finé, one finds the term *tziphra*.[41] In *Arithmetica Integra,* rephrasing Sacrobosco the German Augustinian monk Michael Stifel says »decima autem figura nihil uocata« and »figura nihili« (see also »quam etiam cifram uocant«).[42]

In *Scholae mathematicae* (edition published in 1569), the French humanist and logician Pierre de La Ramée (also known as Petrus Ramus) explains that some say the Indians were the inventors of arithmetic (this is a reference to either the *Liber abaci* or the *Carmen de algorismo*, as they are the earliest to use the expression »Indian figures«) and then clearly paraphrases Sacrobosco while adding his own remarks:

> Circulum appellamus cum multis, quam alii thecam, alii figuram nihili, alii figuram privationis, [...] alii ciphram cum tamen hodie omnes has notae vulgo ciphr[a]e nominentur et his notis numerare idem sit quod ciphrare.[43]

This passage explains that the use of the plural of *cifra* (here spelled *ciphra*) to denote the new numerals (that is, Indo-Arabic figures) developed among the common people (*vulgus*), thus at the level of speech and colloquial language. What is more in »[...] notae vulgo ciphr[a]e nominentur« the evident contrast between *notae*, which we have mentioned as one of the Latin terms used to denote Roman figures, and *cifrae* to denote the new figures.[44] Finally, this noun is the basis of a

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[38] This passage rephrases the *Liber abaci*.
[39] Available at https://archive.org, p. 9.
[40] Smith and Karpinski (1911: fn 211) also mention that Elia Misrachi (1455–1526), a Jewish mathematician, explains *sifra* as being an Arabic term.
[41] Text available online at https://archive.org, p. 7.
[42] Available at https://archive.org, p. 126.
[43] Available at https://archive.org, p. 133.
[44] On a similar note, see the passage in French by Jean Nicot quoted in the next section.

novel morphologically derived form, the denominal verb *ciphrare,* meaning »to calculate« (see *numerare*) with Indo-Arabic figures.[45]

In *De Numeris et Diversis Rationibus,* the German mathematician Johannes Scheubel (1545) says »zifra & nulla uel figura nihili« (1). In *Institutiones Mathematicae* (1593), the Swiss mathematician Dasypodius uses the terms *zyphra* and *syphra*.[46]

As for non-mathematical sources, the form *ciphra* is found in *Annales monasterii S. Albani* (1421–40) of the English John Amundesham (fl. 1440), and *chifra* appears in an anonymous work (prior to 1550) made up chiefly of extracts from William of Ockham's *Tractatus de principiis theologiae*.[47]

In sum, among the early thirteenth century Latin numeral-words denoting the new symbol ›0‹, *cifra* and *nihil* spread quickly and were popularized by the adoption of Sacrobosco's and and Villadei's *algorismi* at university-level and among intellectuals across Europe. *Cifra*, initially a numeral-word used in Latin, was metonymically reinterpreted in popular usage, probably by those who did not know Latin, and, as shown below, was fully integrated into vernacular language. *Circulus,* defining the number zero according to its shape as a figure, had less success and ceased to be used; *zephyrum* firstly appears in the *Liber abaci,* which addressed an audience of both intellectuals and professionals (merchants, architects, bankers, and so forth). Although this text had a stronger impact in Italy than elsewhere, the form *zero* spread beyond the Italian peninsula.

3.2 Evidence from Italo-Romance

Our analysis shows that in Italo-Romance two numeral-words were initially used, one (*cifra*) eventually undergoing changes in meaning and the other (*zero*, with all its variant forms) becoming the dominant and only name for ›0‹. Latin *cifra* gives Italian *cifra*, which is attested earlier than *zero* and, most importantly, not as a numeral-word but already as a word which entered the lexicon acquiring new meanings: the technical word *cifra* was integrated into the vernacular and, in the process, acquired new figurative meanings (connotations) associated with its original denotation (the name for a quantity which is ›nothing‹). Our findings are obviously based on partial written evidence: we could speculate that, initially, Italian *cifra* was the numeral-word used by intellectuals (those who knew Latin), whereas vernacular forms of Latin *zephyrum* were appropriated (and phonologically changed) by less educated people such as merchants, at the colloquial level. While it is true

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[45] See Smith and Karpinski (1911: 234 f.); in book II of *Arithmétique* (1555) by the same author, one finds: »circulus quae nota est ultima: nil per se significat«. Smith and Karpinski (1911: 236 f.) quote several early sixteenth century authors who comment on the terms for ›zero‹ and its value.

[46] Available at https://archive.org, p. 26.

[47] For both references, see the *Dictionary of Medieval Latin from British Sources*.

that Leonardo wrote the *Liber abaci* in Latin, the audience he intended to address was mainly composed of professionals and merchants, as he dedicated a voluminous section to commercial arithmetic and financial transactions. Vernacularizations of his work may have well circulated among merchants earlier than the surviving evidence shows.[48]

To judge from the online database *Opera del Vocabolario Italiano* (henceforth OVI),[49] *cifra* is attested earlier than *zero* but, as we have mentioned, not as a numeral-word: it is found as *zifra* in Jacopone da Todi's (thirteenth century) passage *staraioce per zifra a la mascione* (43, v. 92), [50] which demonstrates that the meaning of *cifra* as ›nothing‹ was already extended in a figurative sense to denote something or someone ›worthless, of no value‹. In the anonymous practical arithmetic work *Livero de l'abbecho*, written around 1289 in the dialect of Perugia (Umbria),[51] *cifra* is a numeral-word, the term for ›zero‹, variously spelled: plural *cifre* (plural), *çiffri cifere*, and *çiffere*. *Cifra* is found in a sentence by Cecco d'Ascoli (ca. 1327): »Fatte sotto gli aspetti delle stelle /con cifre di triangoli e di rombo«,[52] where it is related to geometrical figures and does not seem to mean »zero«. *Zifra* is also found in one of the sonnets (1.10) by Bartolomeo da Sant'Angelo (fourteenth century): »Ed ho en danari ed en libri ed en zoglie, che val ben zento zifre e si è negota«, where the author says that what he owns is worth *zento zifre* (›a hundred zeros‹), thus ›nothing‹.[53]

The earliest evidence of the plural of *cifra* used to denote Indo-Arabic figures appears in an injunction in statutes that the University of Padua passed in 1331 where, most probably for reasons of transparency and to avoid forgery, booksellers are required to make their own name and the price of their merchandise clearly visible on the outside cover, using Roman numerals (*litteras*) rather than the new figures (*zyphras*):

> Ponat eciam in libro venali extrinsecus et in evidenti loco et claris litteris non [per] zyphras nomen venditoris cum ipsius congnomine [sic] et precium libri, sub pena viginti solidorum Universitati solvenda et per rectoris exigenda (Nothaft 2020: fn25).[54]

A similar expression is found in the 1465 statutes of the University of Padua, which obliged booksellers working on the university's premises to display book prices to prospective customers *non per cifras sed per*

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[48] Surviving vernacularizations are from the end of the thirteenth century and the beginning of the fourteenth century (see Van Egmond 1980 and Bocchi 2017), almost one century after Leonardo's work, which seems far too late to be the earliest.

[49] Available at http://www.ovi.cnr.it/.

[50] This passage means »I will be a (mere) cypher in the house«; Gardani (2013: 266) must have misinterpreted this passage, as he suggests that here *zifra* means ›figure‹.

[51] See the edition and study by Bocchi (2017).

[52] Quoted in OVI.

[53] The plural form shows that *zifra* has been reanalysed as a noun.

[54] See the edition by Denifle (1892, 453, ll. 25–28), quoted in Nothaft (2020: fn25).

litteras claras.[55] In *non per cifras sed per litteras claras,*[56] we see the contrast between *cifras,* denoting the newly employed Indo-Arabic figures, and *litteras,* denoting Roman figures, which were based on Roman alphabet.

The first appearance of the Italian variant *cifera* as a technical term indicating what in modern English cryptology is known as ›cipher, coded message‹ appears in the letters by Alessandra Macinghi Strozzi (1406–1471), a Florentine Renaissance businesswoman and noblewoman: first in a letter dated 28 April 1446 and then in a letter dated 20 February 1448.[57] *De componendis cifris* (1466),[58] by Leon Battista Alberti, is widely considered the first and most important Western exposition of cryptanalysis and the first description of enciphered code.[59] It is a cryptography manual, a technical textbook.[60] The author's aim is clear from the very incipit of his work: to provide governors with a way to communicate in a secure way with their most trusted collaborators. It represents a genre which expounds the subject matter in a technical lexicon which includes some key-terms, among them *cifra*. What is relevant to our analysis is that Alberti's work also provides the earliest evidence of Latin *cifra* as ›cipher, coded message‹. *Cifra* is a cryptographic writing system, a procedure of well-defined steps which generate a coded way of writing, employing a set of graphic signs which stand for others. Following Alberti's definition, *cifra* can be described as a way of writing an encrypted message: *inventae sunt scribendi rationes quas cyfras nuncupant* (I, X) »there have been invented some ways of writing which they call ciphers«; *cifram esse rationem scribendi notis ad arbitrium significantibus id quod inter se scribentes constituissent* (X, VIII) is »*cifra* (a cipher) is a way of writing with some characters having a meaning freely established by those who write to each other«. Alberti often uses the plural of *cifra*, for instance *cifris conscribendis* (X, VIII) is »in composing in ciphers«. More specifically, in Alberti's treatise *cifra* is both the cryptographic system and the result of using a ciphering system, namely the cryptogram, the coded message.[61]

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[55] Statuta dominorum artistarum Achademiae Patauinae, [sine loc.]: Pasquino di Roma, [after 1500], fol. 34v (lib. III, c. 24); these statutes are cited by Kirchhoff (1853: 30) and Nothaft (2020: 16).

[56] This expression clearly reflects that *cifra*s were still somehow obscure, while the traditional Roman figures were more easily understood.

[57] Available at <https://archive.org/details/letterediunagent00strouoft> (see pp. 30 and 41); see also Castellani (2000: 243).

[58] Among the fifteen surviving manuscripts of his work, some show the spelling *cyfra*.

[59] An Italian translation was published in 1568 by Cosmi Bartoli; in this work both spellings *cifra* and *cifera* are found. David Kahn (in the preface to Buonafalce 1997: X) argues that Alberti got his ideas from some papal or Florentine cryptologists; on Alberti's treatise, see chapter 1 in Saiber (2017). The French writer on cryptography Blaise de Vigenère published *Traicté des Chiffres* (Paris, 1586), where he mentions Alberti (p. 209).

[60] During the Italian Renaissance, cryptology gained widespread attention.

[61] The Italian term *codice* (›code‹), meaning a system of laws or norms (law code, religious code etc), only later replaced the meaning of *cifra* as ›secret code‹ (see

In the Latin *De rerum inventoribus* by Polidoro Vergilio of Urbino (ca. 1470), an Italian humanist scholar who spent much of his life in England, one finds the term »zipheras« referring to special signs forming an encrypted text, written letters forming words whose meaning was meant to be concealed and which he says to be called »zipheras« by the ordinary people (see the use of *vulgus*).[62] A similar remark appears in *Magia Naturalis* by Giambattista della Porta (first published in Naples in 1558):[63] »De clandestinis literarum notis, quas vulgus zipheras vocat«.[64] On cryptography, Giovan Battista Bellaso published three works: in 1553 *La Cifra, Novi et singolari modi di cifrare* (1555), and in 1564 *Il vero modo di scrivere in cifra*; these cryptography manuals not only show clearly that *cifra* was used to mean both the established method for encrypting and the resulting coded message consisting of ciphered symbols, but it also displays a full development and integration of *cifra* into the Italian language. In Bellaso's work, we find the earliest attestation of the high productivity of Italian *cifra*: see the deverbal nouns *cifrare* (meaning ›to code, write *in cifra*‹) and *decifrare* (›to decode, interpret the ciphered message‹), their participles *cifrato/decifrato* and gerunds *cifrando/decifrando*. In sum, *cifra* as ›secret code‹ developed in Italy as a key technical term within the field of cryptography.

The vernacular form *cifera* appears more frequently some time later than the end of the sixteenth century, it is found in several early printed works; in OVI no instances of *cifera* are found. As for historical dictionaries, no entries for *zero* or *cifra* are found in the first edition (1612) of the *Vocabolario degli accademici della Crusca*.[65] In the *Vocabolario italiano e spagnolo* published in 1706, one finds:[66] »cifera > enigma, cioè detto oscuro che sotto 'l velame delle parole nasconde senso allegorico«. There is also an entry for *cifera*: »cifera o cifra, cioè forma di lettera in carattere e significato straordinario«. The entry for *zero* is: *zero, figura aritmetica , e d'abbaco* [...]. In *Vocabolario italiano e latino: per uso delle scuole di tutti gli stati del Piemonte* (published in 1735), for *cifra* readers are referred to *cifera*; the entry also explains that *cifera* denotes a noun's abbreviated form.[67]*Cifera* seems to have been used at least up to 1850, as it occurs instead of *cifra* as an entry in the

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the expression *un codice segreto*), which eventually came into disuse. Italian *cifrario,* a noun which developed from *cifra* meaning ›secret code‹, entered the language sometime after the 18th century to denote the ›cipher key‹ (the information needed to use the cipher), see *Grande Dizionario della Lingua Italiana*.

[62] Available at <https://archive.org>, p. 99.

[63] A popular work republished in five Latin editions within ten years, with translations into Italian (1560), French, (1565), Dutch (1566), and English (1658).

[64] Available at <http://www.faculty.umb.edu/gary_zabel/Courses/Phil%20281b/Philosophy%20of%20Magic/Natural_Magic/jportab2b.html>.

[65] See <www.accademiadellacrusca.it/it/contenuti/vocabolario-1612/7449>

[66] Available at <https://archive.org>, p. 110.

[67] Available at <https://archive.org>, p. 141.

Vocabolario universale latino-italiano e italiano-latino by Bazzarini pubblished in 1850, where *cifera* (for *cifra,* the vocabulary refers readers to *cifera*) is explained as: »Favellare in cifera, o scrivere in cifera [...]. Scrittore in cifera«. There is also an entry for *ciferista:* »scrittore in cifera o di cifera e cifrare, and cifrare: apporre la cifra o abbreviatura del proprio nome ad alcun' opera«.[68]

The *Grande Dizionario della Lingua Italiana* (henceforth GDLI) specifies (133) that the earlier form of *cifra* was *cìfera* and quotes several passages to illustrate the various meanings and usages of the term, we here summarises the main points: [69] i) by the late sixteenth century the development of *cifra* from the name of the symbol ›0‹ to denote Indo-Arabic figures had taken place, yet in some mathematical works the older terms for ›figure‹ such as *figura* and *carattere* were still found; ii) the meaning ›amount‹ is attested later; iii) the Tuscan Vespasiano da Bisticci (1421–1498) uses the plural *cifere* to indicate writings having a hidden meaning; fifteenth century polymaths Machiavelli and Bembo also use *cifera* with the same meaning.

As for the earliest attestations of *zero*, GDLI (1070–1071) quotes passages by the Tuscan Domenico da Prato (born 1311 CE) and S. Bernardino da Siena (born 1380 CE). To judge from OVI, the earliest attestation of *zero* is found in the mathematical works by the Florentine Paolo dell'Abbaco, born ca. 1282, namely in *Regoluzze* and *Trattato* (both ca. 1374 CE), and in Francesco di Bartolo da Buti (*Commento al Purgatorio,* 1385–94).[70] According to the three surviving manuscripts Jacopo da Firenze's *Tractatus algorismi* was composed in 1307 in Mons Pesulanus (widely taken to be Montpellier), [71] but it has been demonstrated that the three witnesses containing the text are later copies.[72] This is to say that the occurrence of *zero* found in the Vatican manuscript of this treatise (folio 2r) cannot be considered as the first evidence in Italo-Romance. The Milan manuscript (Trivulziana MS 90), ca. 1410 CE, contains the spelling *zevero*.[73] Notably, Jacopo explains that: »Et dovete sapere, et chosì è che el zero per se non significa nulla, ma bene à potentia di fare significare quando è accompagnato [...]«[74] (similar passages are found in many other *abbaco* texts). This seems to be a reworking of Sacrobosco's passage, where one finds the verb *significare* (cf. *significare* in Jacopo) and *locum* (see *posto*). Paolo

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[68] Also, *Instituzioni di aritmetica pratica by* Guido Grandi (published in 1740) shows that the influence of Sacrobosco's work was still active four centuries later, when he uses *cifra* as the numeral-word for ›0‹: »la cifra che per sè sola nulla significherebbe«. Available at <https://archive.org>.

[69] See <www.gdli.it>.

[70] OVI.

[71] English translation and edition by Høyrup (2007).

[72] In this paper, manuscript references are given as found in the catalogue by Van Egmond (1980). Two copies are of the fifteenth century (MS Vat. Lat. 4826 and Trivulziana MS 90), the other of the fourteenth century (Riccardiana MS 2236); see Van Egmond (1980: 148, 166, and 224) and Høyrup (2007: 5).

[73] See Høyrup (2007: 196–197).

[74] See Høyrup (2007: 196).

dell'Abbaco's and Jacopo da Firenze's works belong to the genre of business arithmetic known as *abbaco*; in late thirteenth century Italy, the transition from Roman to Indo-Arabic numerals stimulated a specialized vernacular corpus in the form of the *abbaco* literature, which until the sixteenth century played a major role in instructing generations of young pupils destined to be merchants, bankers, shop-keepers, and artisans.

An unpublished mid-fourteenth century *abbaco* employs the term *zefiro*, while[75] another unpublished *abbaco* manuscript from the late fourteenth century contains the form *zero*.[76] An early unpublished fifteenth century *abbaco* from Cremona (Lombardy) mentions the term *zer(o)* and the other figures in the same way, which clearly rephrases the passage from Sacrobosco mentioned earlier:

> 0 9 8 7 6 5 4 3 2 1 et la decima è ditta nulla over zer over figura de nichil pe(r)ò che i(n) si significa nulla et aconta con le altre fa significare i(n)pe(r)ò che senza zar [sic][77] no(n) se pò scrive(re) lo articulo (MS Ash. 1168).[78]

The form *zero* also occurs in the late fifteenth century Florentine *Trattato d'algibra*.[79] In the first folio of *Arte giamata aresmetica*, a fifteenth century *abbaco* from Lombardy, one finds:[80] »Verbigratia levaremo queste 9 figure, zoè 1 2 3 4 5 6 7 8 9 e queste dese figure, le nove sono significative, la decima non significa nula, zoè 0, ma fa le altre significare com ipsa posta«. In *Tratato d'arismeticha practicha* by Bastiano da Pisa detto Bevilaqua (active in early 1500), one finds *zero:* »poni zero e tieni due decine in mano [...] poni 34 dinanzi al zero«.[81] An unpublished early fifteenth century *abbaco* from Pistoia mentions *çefiro* and explains that: [82] »q(ue)sta altra figura overo segnio ·0· lo quale secondo quelli d'Arabia è apellato çefiro«, clearly rephrasing Leonardo, who specifies that the sign 0 is called *zephyrum* in Arabic. In *Prediche Morali,* (1427 CE), the Franciscan theologian and preacher Bernardino da Siena employs the form *zero* to indicate somebody who is worthless and has no power: »Tu se misero zero e non avrai mai onore«[83]. Also, in another passage: »[...] Egli non è come uno, egli nol merita, egli è zero. Che rileva il zero, o albachista? Per se medesimo, nulla. El zero non può fare nulla senza compagnia. Se tu poni il zero un uno innanzi, egli fa 10, se vi poni un altro zero fa 100«. In this passage, the author rhetorically asks a mathematician (*albachista*) the value of *zero* and explains that its value, when it occurs on its own, is »nothing« but that a number changes

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[75] MS Ricc. 2252/1, 1r, Riccardiana Library, Florence,
[76] MS Fondo principale II.III.198, 1r, National Library, Florence.
[77] On the basis of the evidence found, *zar* seems a scribal error for *zer*.
[78] MS Ash. 1168, 1v, Mediceo-Laurenziana Library, Florence.
[79] See Franci and Pancanti (1988: 8 and 23).
[80] Transcribed by Rivolo (1983).
[81] See Barbieri and Lancelotti (1986: 15 and 24).
[82] National Library, Florence, Baldovinetti 39, 1r-2v.
[83] *Prediche volgari* of S. Bernardino da Siena, edition of 1934, volume I, available at <https://archive.org>, p. 251.

its value when a *zero* is added after it. A Florentine mathematical manuscript (ca. 1470) mentions Leonardo Pisano and *zero*:

> le fighure adunque fatte sono dieci, delle quali le nove significhano alchuno nu(mer)o p(er) se el l'altro che è la decima [...] chiamasi zero [...]. Le nove fighure degli indi sono queste: 9·8· 7· 6· 5· 4· 3· 2 ·1 . Chon questo segnio 0 che in arabo si dice zero si scrive ogni numero [...] 9 fighure significhative e lla diecima chosì quante nulla significha (MS Palatino 573, 1r).[84]

Turning to early printed books,[85] in the first arithmetical work ever printed, *Larte de labbacho* (published in 1478 CE), the term *cifra* as a numeral-word for ›0‹ appears in a passage which clearly resembles Sacrobosco's: »la decima figura. zoe .0. se chiama cifra o vero nulla .zoe. figura de niente perche in se niente leva: ma ioncta a le altre figure: fa crescere il loro valore«. In *Summa de arithmetica* (published in 1494), the mathematician and Franciscan friar Luca Pacioli[86] says: »se dici nulla over çero«.[87] In the *Aritmetica* (published in 1491), the *abbaco* master Filippo Calandri explains that the ten figures were brought from India to Italy by Leonardo Pisano around 1200, that the figures are Indian, and one of these is called *zero* and on its own stands for ›nothing‹: »Dieci le figure con le quali ciascuno numero si può significare: delle quali ne una che si chiama zero: et per se sola nulla significa«.[88] In the popular arithmetic manual by the Venetian Piero Borghi, first published in 1484 in Venice under the title of *Arithmethica,* one finds the form *çefiro*: »la decima è chiamata çefiro, overo nulla, perche in si nulla rilieva ma accompagnata con alguna dele altre fano crescere el valore«;[89] in the later editions of 1540 and 1550, *çefiro* is replaced by *zero*: »la decima è chiamata zero, overo nulla, perchè in si nulla rilieva«.[90] In the popular mercantile arithmetic manual *Libro d'abaco* (1540), the mathematician Girolamo Tagliente provides a passage very similar to Calandri's quoted above (he must have had sight of the latter beforehand); interestingly, he also rephrases passages from both Leonardo Pisano and Sacrobosco, providing the terms for ›0‹ mentioned in the latter's work. Here *figura da niente* renders Latin *figura nihili*: [91] »le qual figure dicono alcuni antichi essere indiane e haverle nel mille e duecento reccate da India in Italia [...] e una che si chiama nulla, cioe figura da niente perche in se sola niente releva«. In Francesco Ghaligai's *Pratica d'arithmetica* (originally published in 1521), one finds *zero* several times (edition of 1552).[92] In

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[84] MS Palatino 573, 1r, National Library, Florence.
[85] Texts in Italian vernaculars began to be printed about 1470. On printing culture in Renaissance Italy, see Richardson (1994; 1999).
[86] It contains a comprehensive summary of Renaissance mathematics.
[87] Available at <https://archive.org>, p. 19.
[88] Published by Morgiani and Petri (1491: 2–3).
[89] Available at < https://archive.org>, p. 2.
[90] Available at <https://archive.org>, p. 2.
[91] The text went through more than twenty-five editions.
[92] Available at <https://archive.org>, see p. 6.

Generale Trattato dei numeri e misure (1556), the Venetian Niccolò Tartaglia mentions Sacrobosco and, in line with the latter's work, says:[93]

> [...] e questo fu trovato di fare da gli Arabi con diece figure, over carattere distinte l'una a differentia de l'altra delle quali nove sono significative rapresentante li nuovi digiti e la decima si chiama da alcuni tecca, da alcuni circolo, da alcuni cifram da altri zerro, e da altri nulla, perchè se sola niente significa e queste figure sono le sottoscritte: 1.2.3.4.5.6.7.8.9.0.

Tartaglia employs the same numeral-words for ›0‹ used by Sacrobosco in the *Algorismus vulgaris* (see *tecca, circolo, cifram, nulla*) but also *zero* (see *zephyrum* in the *Liber abaci*), thereby demonstrating the influence of both Sacrobosco and Leonardo Pisano in the spread of the words for ›zero‹ among intellectuals. The *Practica aritmetica* (written between 1602–1617) by Pietro Cataldi, who taught at the University of Perugia, says: »La prima, che è 0, si chiama nulla, ouero zero, ouero niente«.[94] In *Arimmetica pratica* by Giulio Bassi (published in 1645) one finds: »ma la decima per sé stessa niente significa, salvo se non è accompagnata con qualche altra figura, e questa è chiamata zero, ovvero nulla«.[95] In the *Breve compendio di tutte le regole dell' aritmetica pratica* (publication date 1681), Giacomo Venturoli underlines, as we will show other authors to do in other languages, that *zero* is called as such in Arabic: »con questo segno che in Arabo è detto zero«. This passage clearly rephrases Leonardo's *quod arabice zephirum appellatur*.

Some observations on the phonological development of the word *zero* from *zephyrum* are at this point in order. Its history is far more problematic than is generally acknowledged. We ourselves have yet to find a fully satisfactory explanation of how *zephyrum* could have become *zero*, but we can at least set out here what the problems are. The generally accepted view is that Leonardo Pisano pressed into service the Latin noun *zephyrum* ›west wind‹ to stand for the Arabic word *sifr*—to which it bears some phonological,[96] but rather little semantic,[97] resemblance. It is alleged that *zephyrum* then entered popular usage and underwent phonological reduction to the form *zero* [ˈʣɛro]. Virtually all scholars who have addressed the question accept that some kind of phonological change connects the two forms. Corominas' observation (*CP* s.v. *cero*) that Italian *zero* is an »alteración no bien explicada« of *zephyrum* is an understatement, even if several etymologists and lexicographers (e. g., Pellegrini 1972: 468; Kiesler 1994: 304; Cortelazzo and Zolli 1979–88 s.v. *zero*) seem to accept such a change as straightforward.[98] Corominas

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[93] Available at <www.e-rara.ch/zut/content/zoom/6032277>.
[94] Available at <https://archive.org>, vol. 1, p. 13.
[95] Available at < https://archive.org>, pp. 5, 7, 26– 28.
[96] Corominas s.v. *cero* states that *s.ifr* was ›pronunciado popularmente *s.éfer*‹, thus bringing the Arabic from phonologically closer to Leonardo's Latinization.
[97] The perception of ›the wind‹ as vacuous and invisible yet sensibly real may have played some role in motivating Leonardo's choice.
[98] Meyer-Lübke (1972: 7902a) implicitly recognizes the difficulties of a phonological development of *zephyrum* to *zero* in Italo-Romance, instead

himself, although conscious of the phonological difficulties involved, invokes sporadic deletion of intertonic vowels in Italian as a possible contributory factor in the reduction from a trisyllabic to a bisyllabic form. How the alleged phonetic reduction might have come about has never been seriously examined, however, and the most detailed account of which we are aware remains that of Jordan (1905: 189 f.), for whom the change originated in »dem Dialekte einer der großen Handelsstädte«. It could have occurred, he suggests, according to one of two possible sequences of sound changes: [99]

1) *zefiro* > a. *zefro* > b. *zevro* > c. *zero*
or
2) *zefiro* > a. *zeviro* > b. *zeiro* > c. *zero*

Each of these changes does have some kind of precedent in various central or northern Italo-Romance dialects (cf. Rohlfs 2021: 172 f, for 1a, 302 f. for 1b, 372 f. for 1c;[100] 172 f. for 2a, 292 for 2b, and 33n1 for 2c). Jordan himself mentions that, in Venice, intervocalic [f] can become [v] and may even be deleted (e. g. *scrofa* > *scrova* > *scroa*; cf. 2a and 2c) and that voicing of voiceless consonants (cf. 2c) can occur not only in intervocalic position, but also when preceded by a vowel and followed by /r/ (e. g., Venetian *sora* vs Tuscan *sopra, sovra*, and Tuscan *lira* for *libbra*; cf. 1c). However, the fact that each of these changes may, in some place and at some time, have been *possible* does not mean that either of Jordan's hypotheses for *zero* is plausible. The contrary is true.

First, there is a fundamental problem of chronology: changes 1b and 2a, both involving voicing of an original short voiceless consonant in postvocalic position, span a vast geographical area from northern Italy to the Iberian Peninsula, and are therefore extremely ancient. Moreover, the ancient phonological process of voicing of short voiceless consonants is opacified by the general shortening, in the same geographical area, of original long consonants (cf. Rohlfs 2021: 320 f.) which means that all medieval Italian dialects have instances of postvocalic /f/ not subject to further voicing.[101] Yet Jordan's hypothesis requires voicing of postvocalic voiceless consonants still to have been productive in the thirteenth or fourteenth centuries, which is surely an anachronism.

Second, change 1b is at best marginal and sporadic. The overwhelming weight of evidence from Italo-Romance dialects is that even in inherited, indigenous, vocabulary sequences comprising a labial consonant + /r/ most usually preserve some consonantal reflex of their

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suggesting that the word developed in *Spanish* via the Spanish change /f/ > /h/ > Ø. But see Corominas s.v. *cero* for the historical obstacles to deriving *cero* from *zephyrum* within the history of Spanish.

[99] Skeat (1885:81) states that Italian *zero* is short for *zefiro*, but provides no evidence.

[100] Rohlfs in fact deals here with the fate of the sequence [br], which may in turn become [vr] in some varieties.

[101] Indeed one might ask why we apparently never see a phonologically parallel example of a change *cifra* > **cira*.

labial element (cf. Rohlfs 2021: 371). Consider the following data from the AIS for early twentieth century central and northern Italo-Romance dialects, showing reflexes of LABRA ›lips‹ (map 105), LEP(O)REM ›hare‹ (map 521), FEBREM ›fever‹ (map 697), PAUP(E)RUM ›poor‹ (map 735), LIBRUM ›book‹ (map 763), PIPER ›pepper‹ (map 1010), CAPRAM ›goat‹ (map 1079), AP(E)RIRE ›open‹ (map 1079):[102]

Can this table be adjusted so that words are not split between lines? Maybe reduce font size?

Data from the AIS for labial + [r] sequences

	LABRA	AP(E)RIRE	LEP(O)REM	FEBREM	PAUP(E)RUM	LIBRUM	CAPRAM
Genova	ˈlɛːrfɛ	arˈviː		ˈfrɛːvɛ			ˈkraːva
Milan	ˈlabɛr	dɛrˈviː	ˈleːgura	ˈfɛːver	ˈpoːɛr	ˈliber	ˈkaːvera
Venice	ˈ(l)aːvri	ˈvɛrza		ˈfrevefeːvɐre	ˈpɔːvero	ˈlibro	ˈkaːvra
Bologna	ˈlaːbɐr	avˈriːr	ˈliːvra	ˈfiːvra	(puˈvræt)	ˈliːbɐr	ˈkɛːvrɐ
Florence	ˈlabːri	aˈpriːre	(It. *lepre*)	ˈfɛbbre	ˈpɔːvero	ˈlibro	ˈkaːpra
Pisa	ˈlabːra	aˈpriːre		ˈfɛbbre	ˈpɔːvero	ˈlibːro	ˈ(k)aːpra
Siena	ˈlabːri	aˈpriːre		ˈfɛbbre	ˈpɔːvɛro	ˈlibro	ˈ(k)aːpra

As for Venetian *sora* for *sovra*, and Tuscan *lira* for *lib(b)ra*, cited by Jordan, they may both be special cases, albeit of quite different kinds. *So(v)ra* is a preposition and therefore an extremely high-frequency form, one which is by orders of magnitude more frequent in speech than the innovatory numeral *zero*. It is well known that high-frequency items may be particularly exposed to phonetic erosion not suffered by more rarely used items, and this fact may explain the exceptional disappearance of the labial. As for *lira*, there is some evidence for a change [vr] or [br] > [r] in Tuscany, but it is sporadic. Castellani (2000: 304 f.) cites medieval forms from western Tuscany such as *arà, derà* for *avrà, dovrà* (but here one suspects the analogy of other futures in -V*rà* such as *darà*), *fer*(*r*)*aio* for *febbraio*, and *lira* consistently in the letters of the Pisan merchant Vanni di Stefano. We also find in each of two mid-fourteenth century medieval Sienese texts (the *Libro dell'asse sesto della Compagnia* and the *Libro segreto sesto della Compagnia*), one instance of *liro* for *libro* (cf. also Rohlfs 2021: 372). The form *lira*, although an alleged direct phonological development from *libra*, has the significant semantic characteristic of denoting almost exclusively the unit of currency, not the

[102] Deletion of both the labial and the intertonic vowel is very rare indeed. The AIS map shows some examples in Friulian.

unit of weight. Exceptions, where *lira* means ›pound weight‹, are extremely rare (see *GDLI* s.v. *lira*[4]) and mainly found several times in Sienese writers (Bernardino, Biringuccio). Otherwise, *lira* does not mean ›pound weight‹ while, in contrast, *libbra* could mean either the unit of weight or ›[m]oneta reale di diversi Stati italiani per tutto il Medio Evo e fino all'unificazione nazionale. - Anche: moneta con valore ideale di conto; lira' (*GDLI* s.v. *libbra*[1]$_3$). It was therefore polysemous and potentially ambiguous in mercantile usage. While this is not the place to explore in detail the history of *lira*/*libbra*, the semantic specialization of the form *lira* perhaps suggests deliberate selection by language speakers of a highly localized[103] or at best very infrequent phonological variant adaptation of *libbra* for the specific purpose of differentiating the unit of currency from the unit of weight. In contrast *zero*, even if one derived it from a prior stage **zevro*, offers no such special motivation for the use of an exceptional phonological development. A further problem is that *zephyrum* belongs to learnèd vocabulary par excellence (cf. also Corominas' remark that Spanish *cero* is a ›cultismo‹) and such vocabulary tends to be refractory to, or simply to postdate, indigenous phonological developments. We do have, however, one intriguing example of apparently ›popular‹ forms of *zephyrum* in the sense ›zero‹. A late-fourteenth-century unpublished *abbaco* manuscript[104] says »çeforo overo çerro non significha nulla« (2r) and further on one finds several instances of *çero* (15r)«.[105] The replacement of *y* [i] by *o* is typical of vacillating old Tuscan treatments of intertonic vowels (cf. Rohlfs 2021: 173 f.; Tuttle 1974; Maiden 1995: 45 f.); compare also MESPILUM > *nespolo*, DEBILEM > *debole*.[106] What is quite remarkable is that this form is explicitly equated with an alternative, and apparently also popular, form *çerro* (elsewhere in the same text, *çero*).[107]

Overall, then, if *zero* is related to *zephyrum* via sound change, there remain serious gaps in our understanding of the phonological stages involved. An alternative possibility worth consideration is that the change could be of *graphical* origin, originating perhaps in a schoolroom pronunciation of some abbreviated written representation of *zephyrum*, in which the intertonic syllable were somehow suppressed or

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[103] Meyer-Lübke (1972: 50515) suggests that the word is a loan from Provençal *liura*. The grounds for this suggestion are not given, but if correct it would also be an example of selection of an unusual variant for a specific disambiguatory purpose. The same ambiguity exists in the United Kingdom where ›pound‹ is both a unit of weight (in the imperial measurement system) and a unit of currency, but less so in the United States, where ›pound‹ is normally encountered only as a unit of weight. This might explain why in the UK, but not in the US, the unit of weight ›stone‹ (a unit of fourteen pounds) is also used, thereby somewhat reducing potential confusion between money and weight.

[104] Conv.G.7.1137, National Library, Florence.

[105] Therefore *çerro* cannot be safely interpreted as representing a long consonant.

[106] Such deletions also provoked hypercorrect insertions of an intertonic vowel where none was etymologically justified, as demonstrated, for example, precsiely by the form *cifera* for *cifra* discussed earlier.

[107] The double *rr* is probably a mere graphic sign for [r]: there are certainly examples in the text where *rr* undoubtedly stands for single [r].

indecipherable. Indeed we find that a similar idea had occurred to Spitzer (1956: 281) who remarked laconically that ›[t]he Italian abbreviation of a **zefero* (<low Latin *zephyrum* <Ar. *sifr*) to *zero* is probably rather than of a phonetic (C[orominas] himself confesses that none of his phonetic parallels is convincing), of a graphic nature: *zer*^{o} may have been a written abbreviation which perhaps a connoisseur of the history of Italian book-keeping would be able to attest.‹ Alas, our own survey has so far revealed no evidence whatever for such an abbreviated written representation of the word, so the hypothesis remains moot.[108] In sum, the question of how exactly *zero* is derived from *zephyrum* remains an enigma.

3.3 Evidence in Ibero-Romance and French

The Catalan *Suma de la art de aresmetica* by Francesch de Santcliment, published in 1482, is the first manual printed in Spain to focus on business arithmetic.[109] Santcliment provides some of the earliest evidence in Ibero-Romance of plural *chifres* to denote the new digits: »Elles comunament se appellen chifres mas propriament se appellen figures significatives [...] la deena se appella chifra ho figura de nores, ho altrament alguns la appellen zero [...] le quals 10 chifres se fan en tal manera [...]« (f. 1v). This text focusing on mercantile arithmetic was clearly written for an audience of merchants and readers interested in commercial and practical affairs (the author himself says he had been a merchant trading in Barcelona); the form *zero* also denotes most probably an Italian intermediary (in our French sources, it is not attested earlier than in 1510) and *chifra* indicates that the author also relied on French *algorismi* or later secondary sources. Santcliment uses *chifra* and *zero* (he must have relied or had before him Italian sources) for ›zero‹, and the plural *chifres* to denote the new ›figures‹; such a usage recalls a passage by the French author Antoine Cathalan, who, in the passage *la diziesme est dicte chiffre, qui faict icelles chiffres*, employs the singular *chiffre* for ›zero‹ and the plural *chiffres* for ›numerals‹ (see more in the next section). In the introductory section of the *Suma de arithmética práctica y de todas mercaderías con la horden de contadores* (printed in 1546), Gaspar de Texada says that there are »nueve letras y un zero o cifra«.

The *Arte breve y provechosa de cuenta castellana y arithmetica* (published in 1539) by Juan Gutiérrez uses vernacular *çifra* and *zero,* probably known to him through Italian arithmetic manuals: »çifra o zero [...] nueve figuras [...] con una çifra o zero [...] que no vale nada [...] ma tiene fuerça para hazer valer y aumentar y crescer el valor de qualquiera de las nueve« (4). Juan Pérez de Moya (ca.1513–1596) uses the term *zero* (4) in his arithmetic manual *Aritmetica, practica y especvlativa*.

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[108] For a list of the mathematical manuscripts (1290–1450 CE approximately) which we have inspected, see the reference list.

[109] Available at <https://mdc.csuc.cat/digital/collection/incunableBC/id/25441>. See Karpinski (1936).

In Sebastián de Covarrubias y Orozco's *Tesoro de la lengua castellana* (published in 1611) there is an interesting entry for *cifra* and one for the denominal verb *cifrar* (where *descifrar* is also mentioned, the pair explained to mean ›to code‹ and ›to decode‹), showing that by then not only was the word no longer a numeral-word but that it had become a productive lexeme in Castilian too..: »Escritura enygmatica, con caracteres peregrinos, o los nuestros trocados unos por otros, en valor o en lugar«. Covarrubias y Orozco also attempts to reconstruct the etymology of *cifra*, which he states to be a corruption of *criphia* used by the theologian and encyclopaedist Saint Isidore: »Y el mismo nombre esta corrompido, porque San Isidoro, lib. I, cap. 21, De notis, la llama criphia [...]. Es termini griego y dixose del nombre *kruphios*, occultus«. He then mentions the Spanish philologist Sánchez Brocense (1523–1600), according to whom *cifra* is an Arabic word (cf. the similar observations made by Italian writers). In de Covarrubia y Orozco's dictionary, the entry for *cero* (›zero‹) is: »La figura de la *o* pequeña dicha en Griego omicron [...] numero porque el por si no vale nada, y junto con qualquier otro numero detras del le da valor«.

The 1519 *Tratado da Prática d'arismetyca* by Gaspar Nicolas was the first book on mathematics printed in Portugal; this work is particularly concerned with practical affairs related to commerce and investments; the author refers to ›zero‹ as *çifra*.

One of the earliest instances Latin *cifra* being adapted into French as a numeral-word for the symbol ›0‹ is found in an anonymous thirteenth-century algorism: »Et est d'aucuns chifre apelee, et des maiorz clers nonmee, mais par cifre l'apele l'en [sic] mout plus que par nulle autre rien«.[110] In *Le Triparty en la science des nombres* (1484) by the French mathematician Nicolas Chuquet, the term for ›zero‹ is *chiffre*: »[...] appellee chiffre ou nulle ou figure de nulle valeur«.[111] *Chiffre* is also found in *Larismetique nouellement composée* by the fifteenth French mathematician Etienne de La Roche, whereas the form *zero* appears in the manual on mercantile arithmetic *Le Kadran des marchans* by Jehan Certain, written in 1485. It is interesting to notice that among the four texts here mentioned, only the last is commercial-focused and is the only one to employ *zero,* a term which most probably entered French vocabulary via Italian sources: it is no accident that this work uses the same numeral-word which, as seen in the previous section, is found in mathematical books on practical arithmetic from Renaissance Italy.

An analysis of works published two decades later brings to light an interesting semantic development, because in some texts *chiffre* continues to be the numeral-word for ›0‹ but in others in its plural form it appears to refer to Indo-Arabic numerals. For instance, even in the title of the arithmetic book *Le Livre de Chiffres et de Getz* (Anonymous, 1501), *chiffres* denotes the numerals, while *getz* is ›jetons, counters‹, sort of

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[110] See Karpinski and Waters (1928: 60). Note that Karpinski (1912: 208) also observes that in thirteenth-century France a worthless person was called a *cyfre d'angorisme*.

[111] Available at <https://archive.org>, p. 40. The author also uses the verb »to signify«, which is used in the *algorismi* by Villadei and Sacrobosco, as well.

coins used on the counting board used to learn basic arithmetic.[112] *Le Livre de Chiffres et de Getz* is a vernacular work written for an audience of ordinary people, learners with basic arithmetic skills, and it also teaches both how to compute with the pen by employing Indo-Arabic numerals and how to calculate using jetons on the calculating board. The same terms with the same meanings are found in the *Livre d' chiffres (sic!) et des getz* (anonymous, written in 1509), and several other manuals with similar title produced in larger numbers during the century.[113]

L'Art [et] science de arismetique (anonymous, published in 1510) employs *zero* and *chiffre* as numeral-words: » chiffre ou zero ou figure de non rien«. [114] In the prose-work *Les Illustrations de Gaule et Singularitez de Troye* (1512) by the French poet and historian Jean Lemaire de Belges, one finds *zero* used adjectivally with a figurative meaning to denote a »personne nulle, sans valeur« in *zero au nombre des chiffres*, which also provides evidence of the expression *nombre des chiffres* denoting Indo-Arabic figures.[115] In the anonymous *La manière pour apprendre à cyfrer et compter par plumes et gectz* (published in 1529 in Antwerp), one finds evidence of the verb *cyfrer*, which illustrates a productive word-formation process which the French adaption of Latin *cifra* originated. In the title of the work *La manière pour apprendre à cyfrer et compter par plumes et gectz*, we see the contrast between the verbs *cyfrer* and *compter*: *cyfrer* is a denominal verb (< the noun *chifre/chiffre*) which came to denote calculating by using the *chiffres* (the new figures), whereas *compter* is ›to compute‹ with the pen and the ›coins‹ (*gectz*), thus with concrete objects. The French verb *cyfrer,* also spelled *ciffrer* and *chiffrer,* appears in several titles of arithmetic books of the time; [116] see, for instance, *La vraye maniere pour apprendre à chiffrer et compter* (Lyon, 1535), *L'arithmetique et maniere d'apprendre à chiffrer et compter* by Antoine Cathalan (1548),[117] the *L'arithmetique, pour brievement chiffrer et tenir livres de compte* by Valentin Mennher (1558), and the *Arithmetique facile à apprendre à chiffrer et compter par la plume et par les gects tres-utile à toutes gens* (Lyon, 1594).

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[112] Jetons were tokens or coin-like medals produced across Europe from the thirteenth until the eighteenth centuries; they were employed as counters for use in calculation on a counting board, a lined board similar to an abacus. As Indo-Arabic numerals came into use, ›pen reckoning‹ (see further on the terms *plume* and *pen* in French and English arithmetic manuals of this period) gradually displaced ›counter casting‹ as the common accounting method.

[113] See Wilkinson et al. (2007: 391)

[114] Available at <https://archive.org>, p. 13.

[115] Available at <https://archive.org>, p. 329. See also the entry for *zero* in the *Trésor de la Langue Française Informatisé.*

[116] See Wilkinson et al. (2007); for instance, in the title of a book by Mennher printed several times one finds the verb *cyfrer* in the edition of 1550, then *ciffrer* in the edition of 1564, and *chiffrer* in the edition of 1565 (Wilkinson et al. 2007: 381, vol. 2,)

[117] The edition of 1556 (published in Paris) is available at: <https://jbc.bj.uj.edu.pl/dlibra/publication/870379/edition/836239/content?ref=L3B1YmxpY2F0aW9uLzk0MDY3MS9lZGl0aW9uLzkwNDUzMw>.

In *L'Arithmetique* by the humanist and mathematician Jacques Peletier du Mans (published in 1549), the traditional terms *caracteres, figures,* and *notes*, derived from Latin, define the ten ›digits‹, while *chifre* and *zero* are numeral-words.[118] Claude Boissière's *L'art d'arythmetique* (published in 1554) explains *zero* as follows: »Puis y en a vn autre dict zero lequel ne designe nulle quantité par soy, ains seulement les loges vuides«. [119] In *L'Arithmétique entière et abrégée* (published in 1573) by Pierre Forcadel, professor of mathematics at the Collège Royal in Paris, one finds *cyfre* as well as *nulle* and *rien* referring to the symbol ›0‹. In Forcadel's French version (1582, p. 5) [120] of the Latin *Arithmeticae practicae* by the Dutch mathematician and polymath Rainer Gemma Frisius (1556),[121] one finds: [...] *il y a 10 elemens desquels les neuf sont significatifs et l'autre, qui signifie rien, lequel par la coustume receuë de parler nous nommerons ciphre, zero, rien, ou nulle* [...].Notably, the Latin original by Gemma Frisius gives *cyphra* as a numeral-word;[122] this author also rephrases Sacrobosco's *vel cifra, vel figura nihili quia nihil significant,* where the emphasis is on 0 as a symbol whose value is ›nothing‹.

An intriguing self-explanatory remark is found in *L'arithmétique* (1602) by Jean Trenchant,[123] who, in explaining the workings of the place-value system, says about the term *zero* (p. 12): »En autre langage elle s'apele *chifre,* toutesfois ce mot abusivement prins en François sinifie toutes les figures et l'art d'Arithmetique: de là vient chifrer qui est pratiquer cest art avec ses figures«. [124] On the same page Trenchant also uses the expressions »les neuf figures de chifre«; notably, on pp. 9 and 10 of the above-mentioned work by Cathalan one finds »nombres de chiffres« and on p. 13 »et la diziesme est dicte chiffre, qui faict icelles chiffres«. These expressions demonstrate that the word came to be associated with the new figures, and the meaning developed from this association.[125]

In *L'arithmetique* (1563), written for the needs of merchants and businessmen, Pierre Savonne d'Avignon uses *zero*; in *Les Institutions de l'Arithmetique,* the University of Paris professor Jacques Chauvet

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[118] Available at <https://archive.org>, p. 12.
[119] See Smith and Karpinski (1911: fn 246).
[120] See Bockstaele (1960: 315–321).
[121] Available at <https://archive.org>. This was a successful work, with 100 reprints and translations into Italian and French.
[122] Available at <https://archive.org>, p. 11, see the edition of 1571, pp. 7–10.
[123] Trenchant lived in Lyon, a major financial and banking centre, and dedicated a major section to his book to business arithmetic. The text is available at <https://archive.org>.
[124] »In other speech, it is called *chifre*; however, this word, improperly taken in French means ›all figures and the art of arithmetic‹: from there comes *chifrer,* which is to practise this art with its figures».
[125] Before *chifre/chiffre* became a word to denote Indo-Arabic numerals, the terms used to mean ›digit, numeral‹ by the French authors here presented were *digite, elemens, figure, nombre,* and *caractere*.

Champenois, following Sacrobosco, says (p. 3):[126] »Le dixiesme se nomme chiphre ou zero, ou nul, ou rien«.

Another linguistic comment on *chifre* is found in one of the earliest French dictionaries: the *Thresor de la langue francoyse, tant ancienne que moderne* (published in 1606) by Jean Nicot de Villemain, a French diplomat and scholar, which shows that *chifre* by then was the term for ›digit, number‹, and no longer the numeral-word for ›0‹. This is the entry for *chifre*:[127]

C'est à dire nombre. Il semble estre deriué du mot Hebrieu Sephira, qui signifie nombre. Par ainsi faudroit escrire par s et par ph, siphre. Communément on prend ce mot pour cette sorte de nombre, I. 2. 3. 4. etc. Aussi pour toute escriture faite en characteres inventez à poste, pour n'estre lisables, si n'est par ceux qui ont le contre-chifre, ausquels telle escriture est addressée. Ainsi les Princes escrivent l'vn à l'autre, ne voulants que leur lettre soit entendue, si d'aduenture leurs lettres estoient surprinses.

»That is to say a ›number‹. It seems to be derived from the Hebrew word *sephira*, which means ›number‹. For this reason one should write it with an *s* (thus *sifre*) and with a *ph*: *siphre*. Commonly we take this word for this kind of number: 1. 2. 3. 4, and so forth. So for any writing made in characters deliberately created to be not readable, unless by those to whom such writing is addressed [and] who have the counter-*chifre* (that is, the code to decipher/decode the text). In this way rulers write to each other, when they do not wish their letter to be understood, if their letters were accidentally discovered.

3.4 Evidence in Dutch, German, and English

The anonymous *De manier om te leren cijferen naar de rechte kunst van de algorismi* is the earliest Dutch-language arithmetic book. It was first published in 1508 in Brussels, and several subsequent editions in both Dutch and French translations were printed in Antwerp; parts of this work are translated in the earliest English arithmetic book (first edition in 1537) *An introduction for to lerne to reckon with the pen*.[128] The Dutch edition of 1510, printed in Antwerp, bears the title *Die maniere om te leeren cijfferen ende rekenen metter pennen ende metten penningen*; the verb *cijferen/cijfferen* indicates calculating with Indo-Arabic digits. This provides evidence of the productivity of Latin *cifra* once entered vernacular Dutch.

The great number of printed arithmetic manuals in Germany (the greatest in Europe, followed by Italy and then France) from 1490 to 1595 reflect the strong demand in the local book market for so-called *Rechenbücher* (reckoning manuals), a successful genre in sixteenth-century Germany. Johannes Huswirt rephrases Sacrobosco in

[126] Available at <https://archive.org>.
[127] Available at <https://archive.org>, p.128. Nicot's name was immortalized by the term »nicotine«, the name given to the active ingredient in tobacco, as it was he who introduced tobacco into the sixteenth-century French courts.
[128] See Hoogendoorn (2018: 1008).

Enchiridion novus Algorismi summopere visus de integris (1501) and uses the terms *cifra, theca*, and *figura nihili*. The mathematician Henricus Grammateus, (Heinrich Schreiber) who taught at the University of Vienna, in 1518 published *Ayn new Kunstlich Buech*, where the numeral-words for ›0‹ are *nulla* and *nichts*. In some texts of the first decades of 1500, such as in *Rechenbücher Rechnung nach der lenge/auff den Linien und Feder* (published in 1522) by the reckoning master Adam Ries, one finds the plural *ziffern* to indicate Indo-Arabic numerals. [129] The plural *ziffern* is also used by Jacob Koebel in *Rechenbuch Auff Linien und Ziffern* (published in 1531);[130] notably, in *Ain new geordnet Rechen biechlin auf den Linien mit Rechen pfenningen* (1514), Koebel specifies that »the common people« refers to the »figures« (i. e., Indo-Arabic figures) by the term *zyfer*: »[...] nach/wie má die zale die mit sonderlichen figuren (die der gemain man Zyfer nendt) schreiben folle lernen les enn viind versten [...]«. The term *ziffern* is also found in the 1565 *Rechenbuch, auff den Linien un[d] Ziffern* by the German Rechenmeister Simon Jacob, and in *Arithmetica oder Rechenbuch auff den Linien und Ziffern* by Caspar Thierfelder (1587). All of these four manuals focus on learning to compute on the abacus (see *auff den linien*) and to calculate with the figures (*ziffern*), and are the German equivalents of the previously mentioned French manuals, for instance *La manière pour apprendre à cyfrer et compter par plumes et gectz*.[131] Compare, for instance, the titles of the following three manuals written in three different languages, all focusing both on learning how to use a counting board and on calculating with figures:

French, Anonymous (1529): *La manière pour apprendre à cyfrer et compter par plumes et gectz*

German, written by Jacob Koebel (1564): *Rechenbuch Auff Linien und Ziffern*

English, Anonymous (1574): *An Introduction for to lerne to reckon with the Pen and with the Counters*

In the Latin *Arithmetica Integra* (1544), the German Augustinian monk Michael Stifel refers to the »decima autem figura nihil uocata« and »figura nihili (quam etiam cifram uocant)«.[132] Rudolff, a student of Grammateus at the University of Vienna and the author of the first German textbook on algebra, in his 1526 reckoning manual *Künstliche rechnung mit der ziffer und mit den zal pfennigen, sampt der Wellischen*

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[129] Ries uses the term *nichts* (literally ›nothing‹). His work was the most important German arithmetic manual of the time. His texts were extremely popular, went through at least one hundred editions, and were taught at schools for over a century.
[130] Koebel was a Rechenmeister and the town clerk of Oppenheim.
[131] Maaler (1561), one of the oldest German dictionaries in existence, has no entry for *ziffer*.
[132] Available at <https://archive.org>, p. 26.

Practica und allerley forteyl auff die Regel de Tri, uses *ziffer* for ›digit‹.[133]

England stands out as a latecomer, since the publication of practical arithmetic texts in the vernacular did not start properly before the second half of the sixteenth century, which may explain the conservatism seen in English ›cypher‹ as ›zero‹. Early English arithmetical manuals have continental sources, mainly French and Dutch practical arithmetic works. The earliest known arithmetic printed in English was published anonymous in 1537 and reprinted in London seven times up to 1629, with the title *An Introduction for to lerne to reckon with the pen and with the counters*, a title which is interestingly is modelled upon the French *La manière pour apprendre à cyfrer et compter par plumes et gectz* published in Antwerp in 1529). Richeson (1947) has shown this work to be a compilation, mainly drawing from Dutch and French coeval arithmetic texts;[134] it is worth noting that in the Dutch and French versions one finds the verb *cyffren* and *cyfrer* respectively, but no corresponding forms appear in the English text. The treatise explains that there are ten characters or »fygurs… of the whiche nyne are sygnifycatyue, the tenthe called a siphre signifieng nothyng of itselfe, but set before the other significatyue fygures augmentyth theyr signyfication«. The term used for ›0‹ is *siphre*, the author also uses the expression »fygurs of Algorisme« to denote Indo-Arabic figures and the verb »to signify«, which are found in earlier Latin *algorismi* and were used later by almost all continental sources here investigated. The turning point for the diffusion of practical arithmetic texts in England was, however, the publication of Robert Recorde's *The ground of artes* printed in London in 1543. With its numerous reprints, this is the work that triggered the diffusion of arithmetic primers in England.[135] Recorde provides an interesting remark on the number ›0‹: »signifie nothing, which is made like 0 and is called privatly a cyphar, though all the other sometimes be likewise named«.

The *Crafte of nombrynge* (›Art of Numbering‹) is a fifteenth century CE Middle English anonymous commentary on the thirteenth century Latin *Carmen de algorismo* by Villadei.[136] The author uses the term *cifre* for ›zero‹.[137] The manuscript Ashmole 396 contains *The Art of Nombryng*, which is a fifteenth century English translation/reworking of Sacrobosco's *Algorismus vulgaris*: in the English text *cifre* is ›zero‹:[138] While explaining the working of decimal place-value notation, the authors says: »The .10. is clepede theta, or a cercle, other a cifre, other a figure of nought for nought it signyfiethe. Nathelesse she holdyng that place give the others for to signyfie; for withe-out cifre or cifres a pure article may not be writte«.

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[133] Available at <www.digitale-sammlungen.de>.
[134] See Richeson (1947: 47–56).
[135] Printed at London by H. Bynneman, 1579.
[136] MS Egerton 2622, 136–165, British Museum, London.
[137] Steele (1922: 27).
[138] Steele (1922: 34).

The *Oxford English Dictionary*'s entry for *zero* says that it is: »of multiple origins. Partly a borrowing from Spanish. Partly a borrowing from French. Partly a borrowing from Italian. Etymons: Italian zero; Spanish zero; French zéro«. The entry for *cipher* is: Middle English *sipher, siphre,* 1500s *cyfer, cyfre, cifer, cifra, cifre, ciphra, sypher, syphre, ziphre*; Scottish *syphir, syphyr, (scypher),* 1500s–1600s *ciphre, cyphar,* 1600s *cyphre, ciphar, zifer,* 1500s– *cypher, cipher*.[139] In modern English too, as well as its counterpart in Romance languages, *cipher* is a polysemous word and, as the *Oxford English Dictionary* shows, has been as such already over the last three or four centuries :

1) an arithmetical symbol (0) of no value by itself:
- »Than satte summe, as siphre doth in awgrym«[140]
2) term with a figurative meaning to mean a ›mere nothing‹:
- »He semys to be sumthing worth, that syphyr in bour«[141]
3) a secret manner of writing:
- »We think not convenient to write them, but only in cipher«[142]
4) a hieroglyph:
- »They wolde have deuysed a strange syphre or fourme of letters, wherin they wold have writen their science« [143]
5) In an extended sense, applied to Indo-Aranic numerals as a whole:
- »I reken, I counte by cyfers of agrym»[144]

In his article on polysemy and synonymy and how these concepts were understood in eighteenth-century treatises, and applied in dictionaries of English, Stanley (2004) observes that Samuel Johnson's *A Dictionary of the English Language*, published in 1755, has entries for *nought* and *naught* but not for *zero*, »which he may have felt to be too French», whereas:

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[139] It also says: »medieval Latin *cifra, cifera, ciphra*, < Arabic *ṣifr,* the arithmetical symbol zero or nought, a substantive use of the adjective *ṣifr* ›empty, void‹, < *ṣafara* to be empty. The Arabic was simply a translation of the Sanskrit name *śūnya*, literally ›empty‹.« The Arabic word *ṣifr* was not, however, »simply a translation« of Sanskrit *śūnya* but rather a semantic calque.

[140] (1399) W. Langland Richard Redeles iv. 53. The terms *awgrym* and *augrim* requires some explanation: in several Middle English manuscripts, *algorym* and *augrym* denote Indo-Arabic numerals; these terms are Anglicized forms (perhaps via French?) of Latin algorismus which, as we have seen above is a neologism and Latin adaptation of the Persian proper name al-Khwārizmī. The thirteenth-century *Ancrene Wisse* is an anonymous monastic manual for female anchoresses written sometime roughly between 1225 and 1240 in Middle English; in a passage, one finds that the first recorded mention of *figures of augrim* to denote Indo-Arabic numerals. In A treatise on the Astrolabe (1391 CE), English poet Chaucer uses the expressions *noumbres of augrym* (Part 1, 7), *signes be writen in augrym* (Part 1, 8), and *nombre in augrym* (Part 1, 9).

[141] William Dunbar (died 1520 CE); Bawcutt (1996: 73).

[142] (1528) S. Gardiner in N. Pocock Rec. Reformation I. No. 48. 92

[143] (1541) T. Elyot Castel of Helthe (new ed.).

[144] (1530) J. Palsgrave Lesclarcissement 684/2:

Nathaniel Bailey, from the first appearance of his dictionaries (1721, 1730), had an entry for *zero*, as a word from French and perhaps not felt by him to be fully naturalized: in the small book of 1721, »ZERO, a Word sometimes us'd for a Cypher or nought (0) especially by the French», with nought as synonym; and in the enlarged book of 1730, »ZE'RO, a Name given to a Cypher or (0) especially by the French», without mention of nought. Ash (1775: sig. 6Z2ro) has s.v. zero »(s[ubs tanti ve] in arithmetic) The cypher». Later eighteenth-century dictionaries, perhaps overwhelmed by the authority of Johnson, often have no entry for zero (Stanley 2004).

In nineteenth-century English the verb *to cipher* is ›to calculate, compute‹: see, for instance, the expression *ciphering book*, which denotes a mathematics textbook written in the 19th century, and ciphering with the same meaning in Bronte's *Jane Eyre*. This verb has lost this meaning in modern English.

4. Concluding reflexions on the linguistic history of *zero* and *cifra*

We argue that the semantic development of *cifra* involves metonymy. ›0‹ embodied a new symbol, concept, and digit. The other 9 digits were also new figures (see Roman II versus Indo-Arabic 2) but, unlike ›0‹, their corresponding numeral-words (see *due*, *dos*, and so forth) and numerical values were not new, they did not change after the transition from Roman to Indo-Arabic numerals. The numeral-word *cifra* was a new term for a new numerical symbol. The Latin terms devised for the new symbol came in the vernacular (Italian seems to be the first) to denote all of the new numerals, and eventually to replace *figura, nota, caracter,* and *littera*—earlier Latin terms used to denote the Roman digits based on the letters of the Roman alphabet. The shift of *cifra* from being the name for the symbol ›0‹ to denote, in the plural, the Indo-Arabic figures involves the replacement of its original meaning with one commonly associated with the concept it embodies. This shift must have happened in the usage of the common people, as several fifteenth and sixteenth authors highlighted. The lexeme *cifra* has undergone a process of full integration into various languages. In Italian and other Romance languages *zero* is also morphosyntactically integrated into the numeral system: like all numerals other than ›one‹ it selects a *plural* noun, even though it does not in fact express a plurality. Just as we have *dieci gatti* we have *zero gatti* (not **zero gatto*).

We have shown that *cifra* is an instance of productive lexicalization of a neologism, on the basis of which new words are formed according to established and productive patterns of derivational morphology, as seen in the formation of the Italian verb *cifr-are,* French *cyfr-er*, with further affixation in Italian *de-cifrare* (›to decode‹) and French *dé-chiffrer* meaning ›to decode‹,[145] and Italian *cifrario* (attested in later nineteenth

[145] See also the English verb *cipher* (meaning ›to write in code‹) *decipher* (›to decode‹). In modern German, *Chiffre* (a Gallicism) also is a technical term for ›code‹.

century to denote an algorithm used to create a secret message or to make meaning of a secret message).[146] Italian *cifrare* did not develop the meaning of ›calculating with Indo-Arabic figures‹, unlike French and Dutch, but at the time of the spread of manuals on cryptology it came to denote ›to code‹. In modern Italian and modern English this verb is used with this meaning only in the technical field of cryptology. A process of word-formation is productive when it produces »new complex words according to the word formation rules of a given language at a given point in time« (Plag 1999: 6). Modern *cifra* (Italian), *chiffre* (French), *cifra* (Spanish, Portuguese), *cifră* (Romanian), *ziffer* (German), Dutch *cijfer* (< Latin *cifra*), Polish *cyfra,* and Danish *ciffer* all ultimately descend from Latin *cifra* (through different intermediaries), and denote the figures currently used worldwide (Indo-Arabic), while in some languages these descendants of Latin *cifra* mean ›total amount‹ and ›code‹. While *cifra* shows productivity, it is worth noticing significant *zero* does not seem to have participated in the formation of new words, apart from modern Italian verb *azzerare* ›to zero, reset to zero‹.

This corpus-based linguistic investigation has shed new light on the semantic history of *zero* and its phonological development from Latin *zephyrum*, which we have demonstrated to be more problematic than is generally acknowledged. If *zero* really is related to *zephyrum* via sound change, there still remain serious gaps in our understanding of the phonological stages involved. The hypothesis we considered is that the change could originate perhaps in a schoolroom pronunciation of some abbreviated written representation of *zephyrum*. Yet if this is the explanation, evidence for it remains elusive. But however it first emerged, we have charted the circulation and development of *zero*-related vernacular forms in arithmetical manuals, historical dictionaries, and literary works mainly written in French, Spanish, German, English, and Dutch. Another term here which has been thoroughly investigated here for the first time is Italian *cifra*, originally also a numeral-word to indicate the mathematical symbol ›0‹ in medieval Latin. Over time, Italian *cifra* came to indicate Indo-Arabic figures generally, but also to mean »secret writing«, »abbreviation« and »amount«. *Cifra* also developed into a polysemous word in other European languages, yet tracking its history still remains challenging.

Our attempt to solve hitherto unresolved aspects of the linguistic history of *zero* and *cifra* has also illustrated a complex picture of crossing traditions, language contact, reception and adaptation of new knowledge, and wide text circulation. The study of *zero* highlights the truth of the general considerations which follow. The history of the spread and development of terms to denote ›0‹ begins with the widely circulated early thirteenth-century Latin works of Leonardo Pisano, Villadei, and Sacrobosco and then follows a complex, multi-layered route; these authors set a model upon which later writers relied (directly or indirectly through secondary sources) and considered as authoritative. We can identify three parallel traditions of mathematical

[146] See GDLI, s.v.

writing between the early thirteenth and mid-sixteenth centuries: Latin university textbooks, vernacular books addressing an educated audience, and vernacular arithmetic manuals often written by reckoning masters for a wider audience of professionals and common people in need of basic arithmetic knowledge. Practical arithmetic manuals exhibit a high degree of standardization both of language and of mathematical topics, stimulated by the advent of printing. The diffusion of written information in print went in tandem with the demands of a growing market, where mathematical manuals in printed form could reach and educate a much larger audience.

This investigation has presented the first thorough comparative cross-linguistic analysis of numeral-words to denote the symbol ›0‹, presented new evidence, and identified some major problems in our understanding of the histories of *zero* and *cifra* which remain to be resolved. Further investigations are necessary to expand upon the kinds of conclusions that we draw from this study; for instance, illustrative examples of *zero* and *cifra* as found in historical administrative records and private notebook is likely to be revealing and could constitute the object of future archival research.

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