# On the Subitizing Effect in Language Contact

**Francesco Gardani and Chiara Zanini**

**Abstract** Numerical cognition is an essential component of our daily life. It is the ability to process numerical quantities. In language, symbolic representations of numerical quantities are encoded by numerals. In situations of language contact, numerals are often borrowed from one language into another (Haspelmath & Tadmor, *Loanwords in the world's languages: A comparative handbook*. De Gruyter Mouton, Berlin, 2009), and it has been observed that high and more abstract numerals are more prone to borrowing than lower numerals (Matras, Yaron, *Language contact* (Cambridge Textbooks in Linguistics). Cambridge University Press, Cambridge, 2009: 202). Linguists mainly explain the higher borrowability of high numerals in sociocultural terms, for example, because of "their association with formal contexts of use" and "through intensification of economic activity" (Matras, Yaron, *Language contact* (Cambridge Textbooks in Linguistics). Cambridge University Press, Cambridge, 2009: 200). We propose an alternative explanation, informed by cognitive science, showing that low numerals are more resistant to borrowing than high numerals because they are more deeply anchored in cognition.

**Keywords** Borrowing · Language contact · Lexical borrowing · Linguistic typology · Numerals · Numerical cognition · Subitizing

## 1 Introduction

Numerical cognition is an essential component of our daily life. It is the ability to process numerical quantities. In language, symbolic representations of numerical quantities are encoded by numerals. Numerals are a near-universal category in

F. Gardani (✉) · C. Zanini
University of Zurich, Zurich, Switzerland
e-mail: francesco.gardani@uzh.ch; chiara.zanini@uzh.ch

language. Almost all languages of the world have number words, but they vary considerably with respect to how they encode numerosity[1] and which quantities they encode: some languages have an unlimited number of terms for quantities; others, such as some Australian (Zhou & Bowern, 2015) and Amazonian languages (Epps, 2013), have restricted numeral systems that extend only as far as 3 (e.g., Mangarrayi) or 5 (e.g., Yidiny) (Comrie, 2013); to date, researchers have identified only one language apparently missing numerals, namely Pirahã (Gordon, 2004; Everett, 2017).

In situations of language contact, numerals are often borrowed from one language into another (Haspelmath & Tadmor, 2009). However, not all numerals are borrowed equally, as low numerals are borrowed less frequently than high numerals (Greenberg, 1978; Thomason & Kaufman, 1988: 74; Matras, 2009: 202). Well-known cases include Japanese where "[w]ith a few lexical exceptions, the native system is now used only up to '10'; above '10', even those counters which prefer the native numerals must use the Chinese set" (Martin, 2004: 767). Often, however, only the lowest numeral range is resistant to borrowing: for example, in Yakkha, a Sino-Tibetan language spoken in parts of Nepal, Darjeeling district, and Sikkim, all numerals above 'three' are borrowed from Nepali (Schackow, 2015: 106). To explain this dissimilar borrowing behavior, linguists have resorted to sociolinguistic factors, such as the dominance of a language community over another, in terms of trade and education (Matras, 2007: 50–51). While this claim is virtually correct, it fails to capture some facts, for example, why it is precisely the group of the lowest numerals (one to three/four) that is more resistant to the pressure exerted by language contact. In this paper, therefore, we propose an alternative explanation, informed by cognitive science, which—we argue—will not only complement but also surpass the sociolinguistic explanation: we explore the hypothesis, informed by cognitive science, that lower numerals are more resistant to borrowing than higher numerals because the mental representation of the former is much more precise, more deeply anchored in cognition, and therefore less susceptible to change.

The article is structured, as follows. Section 2 details the two parallel and dissociated core systems responsible for non-symbolic and non-verbal numerical cognition, viz. the Parallel Individuation System and the Approximate Number System, and the two ensuing processes of enumeration, viz. subitizing and counting. Section 3 provides evidence for the interaction between numerical cognition and language in both monolingual and bilingual contexts, showing that the encoding of numbers and numerosities in language echoes the type of information processed by the non-verbal numerical systems. In Sect. 4, we explore the possibility that numerical cognition also plays a role in language contact and make the hypothesis of a subitizing effect on the borrowability of numerals. Section 5 illustrates the language sample, the dataset we built to test the subitizing effect hypothesis, and the statistical tests we performed on the data. The results are discussed in Sect. 5.3. Section 6 concludes the article.

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[1] The term 'numerosity' was introduced by Nelson & Bartley (1961: 179). According to Ramirez-Cardenas & Nieder (2019: 102), it can be defined as "[t]he number of items in a set".

## 2  Numerical Cognition

Numerical cognition is the ability to process numerical quantities represented either symbolically (e.g., by the word *two* or the Latin digit *II* for the numerical quantity 2) or non-symbolically (e.g., by a set of two visual objects) (Piazza et al., 2007: 165). Symbolic numerical representation has been shown to be a cultural invention and language-specific, whereas the non-symbolic representation system does not depend on language competence, but rather relies on the core knowledge systems. The core knowledge systems are a set of non-verbal cognitive skills that allow humans to represent the most salient aspects of the environment, such as inanimate and animate physical objects, places in the spatial layout with their geometric relationships, time and numbers (Vallortigara et al., 2010), and to behave accordingly (Carey, 2009; Dehaene, 2011; Spelke, 2000). These skills seem to have played a crucial role in evolutionary success: they are present from birth in humans and are phylogenetically ancient, as they are mostly shared with non-human animal species (Cantlon & Brannon, 2007; Rugani et al., 2015; Spelke, 2000; Starr et al., 2013).

In every-day life, people resort to language while performing calculations and for this reason, mathematical reasoning would appear to be impossible to perform without the support of words and symbols. Recent studies, however, have shown that language is not a necessary condition for mastering basic numerical abilities (for a review cf. Gelman & Butterworth, 2005). This view is backed by the fact that numerical tasks can be solved also by non-human animals (Agrillo et al., 2007, 2014; Cantlon & Brannon, 2006; Rugani et al., 2013; Vallortigara, 2012), pre-verbal infants (de Hevia, 2011; de Hevia et al., 2014; McCrink & Wynn, 2007), adults who speak languages that (appear to) have no number words (Butterworth et al., 2008; Pica et al., 2004) and even educated adult humans under specific experimental conditions that prevent the use of language (Cordes et al., 2001).

Non-verbal numerical cognition is, in fact, thought to be based on two parallel, and dissociated, core systems: one system—labeled Parallel Individuation System (PIS, also known as 'object tracking system' in Shettleworth, 2010 or 'object file system' in Rugani, 2017)—is responsible for representing small sets of items (from 1 to 3–4). The other system—the Approximate Number System (ANS, also known as 'analogue magnitude system')—is responsible for approximate quantity estimation (Carey, 2009; Feigenson et al., 2004; Hyde, 2011; Hyde & Mou, 2016; Tzelgov et al., 2015).

The PIS allows human and non-human animals to identify a new object when this enters a real scene and to dedicate to it a corresponding file that is held in the working memory. The number of the files that can be simultaneously tracked and stored is usually limited to three or four (Trick & Pylyshyn, 1994; for differences across species as concerns the upper limit, cf. Carey, 2009). Thus, the effectiveness of this system—that allows enumeration without counting—relies on perceived spatio-temporal information and property changes. In other words, the PIS is based on the visual system used to localize and track objects in space (Dehaene, 2011: 57). It follows that PIS is not specific to number representation and, hence, number is

just implicitly represented as the result of a series of visual operations. By contrast, the ANS is assumed to handle larger numerosities: it "allows individuals to perceive and approximately estimate numerosity without counting and using symbols" (Tikhomirova et al., 2019). This ability is generally measured by non-symbolic comparison tests in which individuals are asked to compare two arrays of objects (mostly dots) and to determine which array is larger or smaller (e.g., Smets et al., 2016). The ANS is ratio-dependent in compliance with Weber's law: as the ratio between the numbers to be discriminated increases, response times decrease and response accuracy increases (Gallistel & Gelman, 1992). Numerical discrimination becomes more precise with age (Halberda & Feigenson, 2008; Feigenson et al., 2004; Izard et al., 2009). For example, newborns can successfully discriminate arrays with a minimum ratio of 1:3 (e.g., 8 vs 24), while infants can estimate arrays with a 1:2 ratio at 6 months (e.g., 8 vs 16) and arrays with a 2:3 ratio at 9 months (e.g., 8 vs 12). The minimum discernible ratio increases for preschool children (3:4), and adults can discriminate ratios as small as 7:8.

The hypothesis of the independence of the mechanisms underlying the perception and representation of small vs large numerosities, viz. Parallel Individuation System vs Approximate Number System, is supported by several studies. For example, Hyde and Spelke (2011) measured event-related potentials (ERPs) activity in 6–7.5 months old infants while they were looking at either small (1–3) or large (8–32) sets of objects. The authors reported that small numbers were associated to an early occipital-temporal response peaking at about 400 ms, regardless of their ratio. By contrast, larger numbers were associated to a mid-latency parietal response, peaking at 500 ms, that was dependent on the ratio between successive large numbers. Evidence also comes from recent studies on children with developmental dyscalculia, showing that subitizing was intact, whereas large numerosity comparison was impaired (Decarli et al., 2020). Consequently, two processes of enumeration can be identified: 'subitizing'—the ability to enumerate small quantities (1–4 objects) in a rapid (40–100 ms/item), effortless, and accurate way (Kaufman et al., 1949); and 'counting'—the ability to process more than 4 items, which is slow (250–350 ms/item), effortful, and error-prone (Trick & Pylyshyn, 1994). Numerals from 1 to 4 belong to subitizing, obey a pre-attentional mechanism, they are so to speak primitive, more natural, more immediate (Green, 2017), whereas higher numerals belong to counting and are a result of enculturation. (But note that Frank et al., 2008: 819 consider "language for exact number [...] a cultural invention rather than a linguistic universal".)

Although the dissociation between the two core systems responsible for nonverbal numerical cognition has been observed across human and non-human animals (Hubbard et al., 2008; Hurford, 1987; Kawai & Matsuzawa, 2000; Posid & Cordes, 2015),[2] the core system underlying subitizing has been claimed to be "both ontogenetically and phylogenetically primitive" (Hauser & Spelke, 2004: 861), and

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[2] In non-human animals, the ANS has been found consistently in trained animals, from apes to bees, but also in numerous vertebrate species (cf. Nieder, 2020 and references therein).

subitizing has been claimed to reflect fundamental perceptual, attentional, and cognitive capacity limitations such as working memory storage capacity (Cowan, 2001, 2010); according to Dehaene (2011: 80), "[w]hen our species first began to speak, it may have been able to name only the numbers 1, 2, and perhaps 3". Crucially, subitizing is ontogenetically primary as it develops before counting, as studies on infants have demonstrated (Starkey & Cooper, 1995).

## 3   The Signature of Numerical Cognition in Language

As we have seen, both core systems responsible for non-verbal numerical cognition, viz. PIS and ANS, are shared by human and non-human animals. By contrast, the symbolic representation of numerosity is argued to be "unique to humans and requires the ability to precisely represent numerosity verbally as number words or visually as Arabic number symbols" (Tikhomirova et al., 2019). According to Hurford (1987: 1), "the structure of natural numeral systems turns out to yield a rich vein of evidence that can be brought to bear on central questions of the nature of language, the relation of language to mind and society, and the nature of number." However, reactions to Hurford's input have mostly followed a language-relativistic Whorfian perspective so as to ask whether and, if so, to what extent calculation can be performed without using number words (cf. Pica et al., 2004 on the Munduruku community in the Tapajós River basin and Spaepen et al., 2011 on the Nicaraguan homesigners). The reverse prospective, which pursues questions such as whether cognitive abilities common to humans have contributed to constrain the range of grammatical possibilities and whether such constraints have resulted in crosslinguistic trends (Christiansen & Chater, 2008), has received much less attention. Here, we take this perspective, as we are interested in the question whether numerical cognition shapes the resources that language users resort to, to express numbers and quantities.

As we said in Sect. 2, the non-symbolic representation system—responsible for both subitizing and counting—relies on the core knowledge systems and does not depend on language faculties. However, the symbolic and the non-symbolic systems are not totally independent from each other, rather they interact. Neuropsychological studies have provided robust evidence that the non-symbolic system is fundamental in the construction of the symbolic system and constantly interacts with it (Cantlon, 2018; Furman & Rubinsten, 2012; Notebaert et al., 2011; Piazza et al., 2007; Wynn et al., 2013). This suggests that access to the symbolic system such as the verbal representation of numerosity in language can imply access to the non-symbolic system. Clear evidence for the interaction of the two systems comes from the so-called SNARC (Spatial-Numerical Association of Response Codes) effect (Dehaene, 2011; Dehaene et al., 1993; Fischer & Shaki, 2014; Göbel et al., 2011; Winter et al., 2015). The SNARC effect relates to the mental number line in long-term memory, a spatial representation of numbers along a left-right-oriented continuum, such that small numbers would be located on the left side and large ones on the right side

(Galton, 1880). This spatial-numerical association constrains the performance in numerical tasks: as a matter of fact, adults (but also pre-verbal human infants and animals, cf. de Hevia & Spelke, 2009; Rugani & de Hevia, 2017) have been shown to process small numbers faster when their responses are executed with the left hand (e.g., with left side buttons) and to process large numbers faster when their responses are executed on the right hand (e.g., with right side buttons). The SNARC effect has been demonstrated for both Indo-Arabic numeral digits and number words (Landy et al., 2008; Nuerk et al., 2004; Nuerk et al., 2005) and notably, only when the tasks required the semantic processing of numerical magnitude (Fias, 2001). For example, a SNARC effect is reported robustly in parity judgement tasks (in which participants are asked to judge whether number words are smaller or larger than a reference number), whereas it has not been observed in asemantic phoneme monitoring tasks (in which subjects are asked to decide whether or not a certain phoneme is contained in the number word displayed). Roettger and Domahs (2015) found a SNARC-like effect in a series of speeded behavioral response tasks using German words that varied in grammatical number. The authors found that words inflected in the singular had a relative left-hand advantage and words in the plural a relative right-hand advantage, suggesting that grammatical number is also affected by numerical processing. The deep connection between physical size and numerosity (numerical quantity) is also supported by studies concerned with gestures performed while producing linguistic expressions of size, such as the metaphors 'tiny number', 'small number', 'large number', and 'huge number' (Woodin et al., 2020).[3]

Psycholinguistic studies that aim to test models of lexical organization in bilinguals and models of word translation provide evidence that numerical information is accessed during language processing even in multilingual contexts. In three pivotal studies, De Brauwer et al. (2008) and Duyck and Brysbaert (2004, 2008) have shown that semantic processing is almost always activated in translation tasks, especially with words that share similar meanings in both languages and are not cognates (i.e., their forms are not similar). This is precisely the case of number words. The authors conducted several tasks involving bi−/trilingual participants and found a robust SNARC-like effect in parity judgement tasks (in which participants were asked to judge the parity of written L2 number words by pressing a key with the left or right hand) as well as in simple translation judgement tasks (in which participants were asked to specify whether two number words were each other's translation).

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[3] It is worth noticing that there is no consensus on the phylogenic origins of the mental number line. Some scholars have argued that the left-right-oriented continuum is innate, as its signature has been found in several studies of pre-verbal infants and non-human animals (e.g., Rugani et al., 2015; Rugani & Regolin, 2020). Other authors have challenged this view, claiming that the direction of this mental mapping is modulated by one's cultural experience (e.g., Pitt et al., 2021). This debate, however, is beyond the scope of the present article. What is important to stress here is that, even if the direction of the association between numbers and space may vary as a function of exposure to culture and could depend on the direction of writing (so that the SNARC effect can be weakened or reversed in right-to-left writing systems; e.g., Dehaene et al., 1993), the SNARC effect "reflects the automatic activation of quantity information in the subject's brain" (Dehaene, 2011:81).

Notably, this SNARC-like effect—which was unrelated to the participants' L2 proficiency—was interpreted as the signature of conceptual mediation during number word translation (especially when translating from L2 to one's L1). Duyck and Brysbaert (2004, 2008) also reported a magnitude effect as L2 number words denoting small quantities (e.g., *two*) were faster to translate than L2 number words denoting large quantities (e.g., *eight*) (for further discussion cf. also Brysbaert & Duyck, 2010).

All the evidence thus far reported suggests that the structure of languages echoes the information processed by the non-verbal numerical systems. This is, in fact, not surprising. As stated in Sect. 2, non-verbal numerical cognition—as part of the core knowledge systems—is fundamental for biologically successful behavior (Spelke, 2000). If core knowledge information is biologically fundamental to the extent that it constrains numerical cognition even when numerical magnitude is represented and processed symbolically (Cantlon, 2018), delivering this kind of information in a prompt and efficient way, such as by means of language, is expected to be advantageous. A growing body of literature has shown that this type of information can contribute to shaping languages from the lexicon to syntax. For example, using data-driven computational models and performing an analysis on nine different languages, Rinaldi and Marelli (2020) showed that the use of number words in spontaneous language production depends on numerical ratio—a clear signature of Weber's law and of the Approximate Number System (Sect. 2). This system is indeed ratio-dependent: as the ratio between the numbers to be discriminated increases, response times decrease, and accuracy increases. Rinaldi and Marelli (2020) also reported that number words referring to lower numerosities are used more precisely and in more specific contexts than those referring to higher numerosities. In previous work, Dehaene and Mehler (1992) had arrived at analogous results. The authors measured the frequency with which number words are used (both in speech and in writing) in different languages and found that the frequency of numerals decreases systematically with number size, regardless of cultural, geographic, and linguistic differences. Moreover, in languages such as English, words expressing twoness or threeness (e.g., bicycle and triangle, respectively) are by far more type-frequent than those expressing fiveness or large numerosities (e.g., quinquennial). The use of number words resembles those of digits. In this respect, it has been calculated that 1, 2, or 3 are twice as likely to occur as all other digits (Dehaene, 2011). According to Dehaene (2011), the observed distribution of number words in the lexicon of diverse languages is not due to environmental or cultural biases. Rather, the fact that there are more words to denote small numbers and progressively fewer words to denote increasingly larger numerosities, resonates with "the decreasing precision with which numbers are mentally represented" (Dehaene, 2011: 110) so that "numerical regularities in the world seem to be lexicalized only if they concern a small enough numerosity" (Dehaene, 2011: 113).

Evidence for the idiosyncratic character of the lowest numerals (1 to 3 and 4) comes also from within grammar. Because of their indicative-deictic character (Seiler, 1990: 190), very low numerals are often associated with referential functions (determination): for example, the numeral for 1 also serves as an indefinite

determiner in many languages (e.g., *un* 'one / a(n)' in French; cf. Givón, 1981 for a diachronic account on this development drawing on Hebrew examples). The use of the numeral for 1 as an indefinite determiner is attested in a high number of unrelated languages from Mandarin to Native American languages, such as to make it a good candidate for a linguistic universal. An inspection of the WALS Online corpus (Dryer & Haspelmath, 2013) reveals that the numeral 'one' is used as indefinite article in 112 out of 534 reported languages (198 of these have neither an indefinite article nor a definite article; cf. Map 38A by Dryer, 2013b). For similar reasons (e.g., indicative-deictic character), in inflecting languages only the lowest numerals (notoriously those for 1, 2, 3) are sensitive to gender and case distinction (Blažek, 1999; Gvozdanović, 1992; Hurford, 1987: 192). This is the case, for example, in Ancient Greek (*heîs*, *mía*, *he* 'one.M, one.F, one.N'; *treîs*, *treîs*, *tría* 'three.M, three.F, three.N'; *téttares*, *téttares*, *téttara* 'four.M, four.F, four.N'), Latin (*ūnus*, *ūna*; *ūnum* 'one.M, one.F, one.N'; *duo*, *duae*, *duo* 'two.M, two.F, two.N'; *trēs*, *trēs*, *tria* 'three.M, three.F, three.N'), Romanian *unu*, *una* 'one.M, one.F'; *doi*, *două* 'two.M, two.F') and Croatian (*jedan*, *jedna*, *jedn* 'one.M, one.F, one.N'; *dva*, *dvije*, *dva* 'two.M, two.F, two.N').

Importantly, Franzon et al. (2019, 2020) argued that nonverbal numerical cognition also shapes grammatical number. The authors provided typological and neuro-psychological evidence in favor of the hypothesis that the possible range of inflectional number values (as reflected, for example, in the inflection of nouns such as *apple* vs *apples*) parallels the numerosities processed by the non-verbal numerical core knowledge systems. Indeed, grammatical number is a widespread typological feature (according to map 33A by Dryer, 2013a in WALS Online, 90.8% of the considered languages have a grammatical device to convey nominal plurality; cf. Corbett, 2012: 122) and presents a variety of values across languages, including, at least, singular and plural (i.e., the necessary condition for other values to surface), but also dual, trial, (debatably quadral), paucal, greater paucal, and greater plural for two, three, (four), a few, a few more, and excessive number, respectively. However, grammatical number values never denote any exact numerosity beyond the range of 1 to 3 (and 4) and no morphologically encoded number value for, say, 21 has ever been observed in natural languages.

## 4   The Hypothesis: The Subitizing Effect in Language Contact

When communities speaking different languages come in contact with each other (societal multilingualism), or when different language systems coexist in one and the same speaker (individual multilingualism), several parts of a language—a source language (SL)—can be transferred into a recipient language (RL). Which parts of an SL come to be transferred into an RL, and with which frequency this occurs, depends on several factors. There seems to be general agreement on the fact that not

all parts of a language's grammar are subject to transfer to equal extents. This idea is often conceptualized and conveyed in terms of borrowability scales, that is, hierarchies that detail, and in some cases aim at predicting, the likelihood with which some items or components of grammar are borrowed (see useful overviews in Bakker & Matras, 2013: 165–174; Curnow, 2001; Wohlgemuth, 2009: 11–17). As concerns numerals, it has been observed that high and more abstract numerals are more prone to borrowing than lower numerals (Matras, 2009: 202). However, not all numerals are borrowed at the same rate. Crosslinguistic investigations have shown that low numerals are borrowed less frequently than high numerals (Greenberg, 1978; Matras, 2009: 202; Thomason & Kaufman, 1988: 74). This generalization is roughly mirrored in Greenberg's "near-universal" 54: "If an atomic numeral expression is borrowed from one language into another, all higher atomic expressions are borrowed" (Greenberg, 1978). Based on a sample of 27 languages, Matras (2007: 50–51) reported that lower numerals are less likely to be borrowed than higher ones (e.g., *twenty, one-hundred, a billion*) and proposed the following implicational borrowability scale for cardinal numerals:

higher numerals 1000, 100 > above 20 > above 10 > above 5 > below 5.

According to Matras, the split observed between lower and higher numerals would follow from the dominance of a language community over another in formal contexts such as trade, education, and institutional discourse. Clearly, formal contexts more often involve reference to higher numerals and thus foster their borrowing. Conversely, lower numerals, especially the ones expressing quantities smaller than five, are frequently used in casual contexts, a self-explanatory fact for the retention of their native forms.

While this claim seems reasonable, it fails to clarify some points. First, if it is evident that formal contexts almost always require reference to large quantities, it is not as clear why informal contexts would mostly imply reference to smaller quantities. After all, it has been amply shown that our environment is not more frequently composed of small sets of objects than of large ones (Dehaene (2011: 80). Second, from a mere culture-centered perspective, it is far from straightforward to outline the criteria by which a quantity should be defined as small or large. For example, 2 is smaller than 7, and 7 is far smaller than 100. In fact, Matras claims that "conceptual complexity and inaccessibility" play a role, as is evident from that fact that the borrowing ranking for numerals for "0" is closer to that of numerals for "100" and "1000", which he explains with "the ability to easily identify and appreciate a quantity" (Matras, 2007: 52), which does not apply to "zero". And yet, how do we explain the fact that for numerals, such as one, two, three and four, the borrowing chances decrease dramatically? And why is the borrowing threshold almost always set at three/four?

In a paper focusing on Berber varieties, Souag (2007) proposes multiple answers to these questions. As for the numeral for 1, he proposes a frequency-based motivation: the fact that across most Berber languages, the numeral for 1 also serves as a determiner considerably increases its frequency and so discourages its replacement. As for the numerals for "two" and "three", Souag (2007) says that their retention "is

paralleled by several other typological facts", such as the existence of dual and trial—but no higher—number values in a number of languages (cf. Sect. 3). Eventually, Souag (2007: 242) weighs also "cognitive factors, such as the possibility of subitisation and the processes involved".

Putting aside language contact for a moment, we can observe that crosslinguistically, the number of numerals progressively decreases as they encode increasingly larger numerosities. The distribution of numerals in the lexicon as well as their frequency of use across typologically diverse and geographically distant languages appears not to be random or solely attributable to sociocultural factors. Rather, it seems to follow precise patterns that can be captured in terms of cognitive pressures. Specifically, the progressive decrease of number words to designate increasingly larger numerosities seems to reflect the way numerical information is mentally represented and processed. Low numerals encode quantities which are processed via subitizing (Sect. 2); subitizing is a mechanism more deeply anchored in cognition than counting, and this makes low numerals more salient for the speakers. Hence, the fact that, overall, languages have more words to express low numerosities is not because the referential world comprises mostly sets of few items, but because the mental representation of low numerosities is more precise. Further evidence for this is that virtually all languages have at least words to designate low numerosities, and even the very few languages apparently missing numerals show a lexical opposition to distinguish small quantities from relatively larger ones.

In this paper, we propose that the different behavior of low vs high cardinal numerals in language contact is also explainable in cognitive terms, as it reflects the way numerical information is represented and processed in the brain. Specifically, we argue that lower numerals undergo borrowing less frequently than higher numerals as an effect of subitizing: the mental representation associated to the lowest numerals (*one, two, three*, and possibly *four*) is much more precise, more salient, more deeply anchored in cognition, and therefore more stable and less susceptible to change. In other words, while sociocultural pressures can certainly play a role in the borrowing of high numerals (Matras, 2007: 50–51), their impact on low numerals is countered by phylogenetically ancient and evolutionarily successful cognitive abilities which have also been shown to affect language processing. In the next section, we detail the language sample we have built to test our hypothesis and present the results of our investigation.

# 5 Data and Analysis

## 5.1 Dataset and Methods

In order to test the hypothesis of a subitizing effect on the borrowability of numerals (Sect. 4), we created a language sample that includes:

- 25 typologically diverse recipient languages, comprising one creole, one isolate language, and 23 belonging to 15 language families (Afro-Asiatic, Austroasiatic, Austronesian, Hmong-Mien, Indo-European, Japonic, Khoisan, Matacoan, Nadahup, Niger-Congo, Nilo-Saharan, Sino-Tibetan, Tai-Kadai, Tupian, Uto-Aztecan), spoken in four geographical macro-areas (Africa, Europe and Asia, North and Central America, South America, and the Pacific);
- only languages in which at least one numeral from "one" to "ten" has been borrowed;
- creole languages, only as they secondarily borrow from other languages, that is, the use of numerals already existing in a creole's lexifiers is excluded, as it is not considered as borrowing (cf. Gardani, 2008, 2012, 2018, 2020b);
- only cases of borrowed numerals in the sense of matter borrowing, that is, the takeover of concrete (phonological and morphological) material (cf. Gardani, 2020a).

We focused not on whether numeral borrowing is possible at all, but on which numerals are borrowed, when numerical borrowing occurs. For this reason, among others, our sample is smaller than samples used for lexical borrowing in typological research such as Haspelmath and Tadmor (2009), which counts 41 recipient languages.

We analyzed our data by means of the R software (R Core Team, 2020). First, we calculated the proportion of borrowed and inherited forms per each numeral and, controlling for lexical variants, counted the ratio of borrowed numerals for which there exist no further inherited variants to borrowed numerals for which there also exist non-borrowed variants. Then, following Baayen (2008) and Tagliamonte & Baayen (Tagliamonte & Harald Baayen, 2012), we investigated the differences in the proportion of borrowed and inherited forms per each numeral by means of conditional inference trees and random forest, making use of the party package in R (Strobl et al., 2007; Strobl et al., 2008; Hothorn et al., 2006). These non-parametric models[4] are particularly suitable when the sample size is small while the number of predictors is high, and are robust in case of outliers; moreover, "random forests allow the researcher to explore more aspects of the data and by consequence more insights into the explanation for variable processes" (Tagliamonte & Baayen Tagliamonte & Harald Baayen, 2012: 163). We fitted a random forest model to inspect the importance of the variables that possibly come into play in the borrowing of numerals, considering the type of etymon (inherited vs borrowed) as the dependent variable and the type of numeral (from 1 to 10), the language family, the geographical area, and the presence of non-borrowed lexical variants (yes/no) as

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[4] The algorithm tests the association of each independent variable with the dependent variable and chooses the independent variable with the strongest association. On this basis, it parts the dataset in two subsets. The algorithm recursively repeats this sequence (i.e. choosing the best association and further splitting the dataset) until no variables can be associated with the outcome. The results are plotted as a tree structure. A random forest can be grown from many conditional trees and returns the importance measure of each independent variable averaged over many conditional trees.

predictors. We also fitted a conditional inference trees model using the same predictors to check how these variables operate together.

## 5.2  Results

The results of the data analysis are summarized in Table 1. For the actual data see *Appendix 1*. We found that the ratio of borrowed forms increases as the numerosity denoted by the numerals increases and noticed that a threshold obtains between the group of numerals ranging from 1 to 3 (borrowed forms: 18.18% to 26.66%) and the group of the numerals ranging from 5 to 10 (borrowed forms: 48.48% to 70%). The numerals encoding 4 display a behavior in-between, while being slightly more inclined towards the group of the lowest numerals than that of the higher numerals in the data set.

Figure 1 illustrates the proportion of *all* borrowed and *all* inherited forms per each numeral. Here, borrowed and inherited forms show an opposite trend. While the borrowed forms increase progressively in correspondence with higher numerals, the inherited forms decrease. Here too, a clear threshold can be observed between the group of numerals ranging from 1 to 3 and that of the numerals ranging from 5 to 10.

Further, we counted the ratio of borrowed numerals to borrowed numerals for which there also exist non-borrowed variants. We found that, when numerals belonging to the range from 1 to 4 have been borrowed, there mostly also exist inherited correspondents or a non-borrowed series. As shown in Table 2, the ratio of borrowed numerals to numerals for which there are non-borrowed variants decreases progressively, with only numerals for 10 displaying a deviant behavior.

In the random forest model, the variable importance scores revealed that the type of numeral (0.148) is by far the most important predictor when analyzing the probability for a borrowed numeral form to occur. Some predictivity can be spotted also for the language family (0.071) and the presence of non-borrowed lexical variants (0.030), whereas the geographical area does not seem to contribute statistically significant effects. The index of concordance for the model with this set of predictors is equal to C = 0.94.[5] The impact of variables is plotted in Fig. 2.

**Table 1**  Ratio of borrowed to total numerals in a 25-language sample

|                       | One   | Two   | Three | Four  | Five  | Six   | Seven | Eight | Nine  | Ten   |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| $\sum$ forms          | 33    | 31    | 30    | 32    | 33    | 28    | 31    | 29    | 30    | 32    |
| $\sum$ borrowed       | 6     | 8     | 8     | 12    | 16    | 18    | 19    | 19    | 21    | 21    |
| Borrowed:Total %      | 18.18 | 25.80 | 26.66 | 37.50 | 48.48 | 64.28 | 61.29 | 65.51 | 70.00 | 65.62 |
| Borrowed:Total ratio  | 0.18  | 0.25  | 0.26  | 0.37  | 0.48  | 0.64  | 0.61  | 0.65  | 0.70  | 0.65  |

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[5]C is an index of the goodness of fit of the model. A C greater than 0.8 indicates that the model discriminates well.
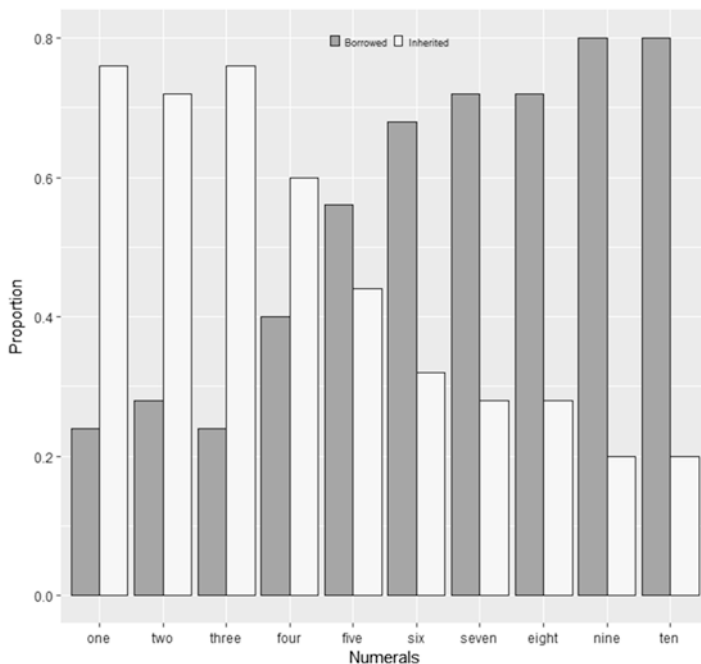
**Fig. 1** Proportion of all borrowed (in dark gray) and all inherited (in light gray) forms across numerals

**Table 2** Ratio of borrowed numerals to borrowed numerals for which there are non-borrowed variants in a 25-language sample

|  | One | Two | Three | Four | Five | Six | Seven | Eight | Nine | Ten |
|---|---|---|---|---|---|---|---|---|---|---|
| $\sum$ **borrowed** | 6 | 8 | 8 | 12 | 16 | 18 | 19 | 19 | 21 | 21 |
| $\sum$ **borrowed of which variants** | 5 | 6 | 4 | 6 | 8 | 4 | 4 | 4 | 4 | 6 |
| **Ratio** | **0.83** | **0.75** | **0.5** | **0.5** | **0.5** | **0.22** | **0.21** | **0.21** | **0.19** | **0.28** |

Consequently, we grew a conditional inference tree (C = 0.85) to check how the predictors evaluated by the random forest interact with each other. All significant predictors in the random forest model were included. The tree and its possible splits are plotted in Fig. 3. The first and most important split (Node 1) separates numerals encoding 1, 2, 3, and 4 from numerals encoding higher numbers. The next split is located in the left branch and divides forms for which a non-borrowed variant is attested from those for which no lexical variant exists. Regarding the latter, a further node (Node 4) parts the data on the basis of the language family. Moving rightwards, Node 7 separates numerals higher than 4 on the basis of the language family and no further split is observed. The bar plots at the bottom show that numerals equal to and lower than 4 are unlikely to be borrowed (cf. Node 6 vs Node 5) and,
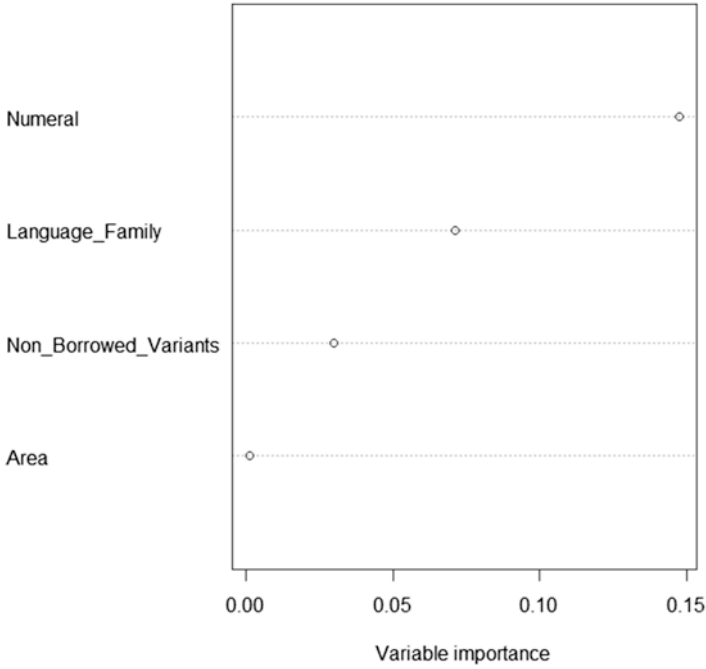
**Fig. 2** Conditional permutation importance of variables in the occurrence of borrowed vs inherited numerals
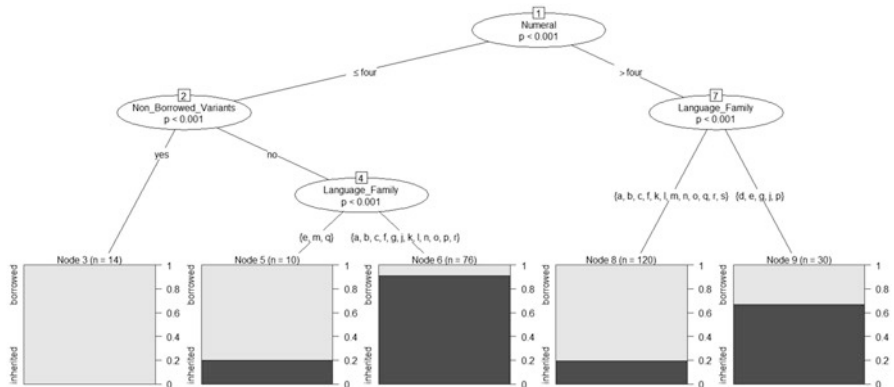


**Fig. 3** Conditional inference tree of the occurrence of borrowed vs inherited numerals. The variables selected for the best split and the corresponding p-values are circled; the branches specify the levels of the variables; the bar plots at the bottom illustrate the proportion of inherited forms (in dark gray) vs borrowed forms (in light gray) in each end node that contains all observations for that combination of features. Language families are indicated by lowercase letters in the plot (a = Austroasiatic, b = Afro-Asiatic, c = Nadahup, d = Japonic, e = Khoisan, f = Indo-European, g = creole, j = Niger-Congo, k = Austronesian, l = Nilo-Saharan, m = Tai-Kadai, n = Sino-Tibetan, o = isolate, p = Hmong-Mien, q = Matacoan, r = Tupian, s = Uto-Aztecan)

if borrowed, non-borrowed lexical variants are also likely to be present (cf. Node 3). Conversely, numerals higher than 4 are more likely to be borrowed than lower numerals (cf. Node 6 vs Node 8) and in this case, borrowability appears to be modulated only by genealogical factors.

## 5.3 Discussion

We provide an analysis of the data along the following lines: First, the results unambiguously confirm the generalization, known from the extant literature, that lower numerals are less prone to borrowing than higher numerals. Second, the data show that in terms of borrowing frequency, there exists a clear threshold between the group of numerals ranging from 1 to 3–4 and that of the numerals ranging from 5 to 10. This perfectly matches with the divide between subitizing and counting theorized in cognitive science. The range from 1 to 3–4 corresponds to the symbolic representation of numerosities that are subject to subitizing. The range from 5 to 10 corresponds to the symbolic representation of numerosities that are processed by counting. We interpret these data as a sign of the signature of cognition in language. Third, the fact that, if the lowest range of numerals are borrowed at all, then still non-borrowed variants exist, further backs our hypothesis of a subitizing effect in language contact.

While the figures we presented in Tables 1 and 2 can be explained in terms of the hypothesis we made in Sects. 3 and 4, they can be just as well accounted for by the sociocultural explanation predominant in the literature (cf. Sect. 1). However, a clear clue that our cognition-based threshold hypothesis is superior comes from the statistical analysis we performed. The trees method makes it possible to measure the importance of the variables at play and, on that basis, to operate the best splits of a dataset. Crucially, our models chose the predictor 'type of numeral' as the most important independent variable in explaining the distribution of borrowed numerals (random forest) and set the first split at 4 (conditional inference tree). In other words, the borrowing dynamics underpinning lower numerals ranging from 1 to 4 appear to be different from those underpinning numerals higher than 4. It is somewhat hard to explain the partitioning of the data by the models from a perspective grounded only on sociocultural factors. Why 4 and not, for example, 5? Ultimately, both 4 and 5 denote low numerosities. In our view, a hypothesis also informed by cognitive science offers a more precise and a falsifiable explanation. While sociocultural variables cannot be completely excluded, especially as concerns higher numerals, our results clearly point to a priority of cognitive pressures in preserving the inherited forms of lower numerals, precisely up to 3–4. Hence, the distribution of borrowed number words across typologically diverse and geographically distant languages, like those included in our dataset, appears not to be random or solely attributable to sociocultural factors. Rather, it seems to follow a precise pattern that can be captured—we claim—in terms of subitizing effects, as proposed in Sect. 4.

# 6   Conclusion

In this paper, we explored the hypothesis that non-symbolic numerical cognition plays a role in language contact, as it influences the borrowing chance of number words in a decisive way. We set out from known facts as to the extent to which numerals are subject to borrowing (their borrowability) in situations of language contact. According to the received knowledge, lower numerals are more stable than higher numerals in that they are observed to resist borrowing more frequently. To date, linguists have explained this pattern mainly resorting to sociocultural motivations, claiming that higher numerals are more prone to borrowing as a consequence of intensification of economic activity and of education. While sociocultural pressures can certainly play a role in the borrowing of higher numerals, in our study we took the perspective of cognitive science and proposed an alternative and—we think—superior explanation.

We argued that lower numerals are more resistant to borrowing than higher numerals as an effect of the way numerical information is mentally represented and processed: very small quantities (up to 3, possibly 4) are processed via subitizing, a mechanism more deeply anchored in cognition than counting that makes the mental representation of low numerosities more precise and, thus, low numerals more salient for the speakers. Accordingly, we hypothesized a subitizing effect on the borrowability of numerals. We tested this hypothesis against empirical evidence drawn from a sample of 25 typologically diverse recipient languages. We performed statistical analysis to investigate the differences in the proportion of borrowed and inherited forms per each numeral by means of conditional inference tree and random forest models. The results unambiguously confirm the prediction, known from the extant borrowability scales, that lower numerals are less prone to borrowing than higher numerals. Crucially, our results show the signature of cognition in language, which is due to the interaction of the non-symbolic and the symbolic systems: in terms of borrowing frequency, there exists a clear threshold between the group of numerals ranging from 1 to 3–4 and that of the numerals ranging from 5 to 10. This threshold—we argue—results from the impact that phylogenetically ancient and evolutionarily successful cognitive abilities have on language processing and thus on borrowing behavior.

# Appendix 1

## Numerals: One–Four (Part A)

| Languages | | | Numerals | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Areas | L family | RL name | One | *B vs I* | Two | *B vs I* | Three | *B vs I* | Four | *B vs I* |
| Europe and Asia | Austroasiatic | Ceq Wong | nɗy | | ber | | pɛt | | pɑn | |
| Europe and Asia | Austroasiatic, Munda | Bondo | mujũ | | mbaru | | iʔŋge | | uʔu | |
| Africa | Afro-Asiatic, West Chadic | Hausa | dɑ̃yá | | bíyú | B, SL Benue-Congo languages | úkù | | húɗũ | |
| South America | Nadahup | Hup | ʔayũ̌p | | koʔãp | | mɔtaʔãp | | hibab'ní | |
| | | Hup variants | | | | | | | | |
| Europe and Asia | Japonic | Japanese | hitotsu | | futatsu | | mittsu | | yottsu | |
| | | Japanese variants | ichi (2) | B, SL Chinese | ni (1) | B, SL Chinese | san | B, SL Chinese | yon | |
| | | Japanese variants | | | | | | | shi | B, SL Chinese |
| Africa | Khoisan | Kwadi | lwí | | lám | | dátũa | B, SL Bantu | né | B, SL Bantu |
| Europe and Asia | Indo-European | Molise Croatian | jena | | dva, dvi | | tri | | četar | |
| | | Molise Croatian variants | | | | | | | | |
| Europe and Asia | Indo-European | Istro-Romanian (Northern) | ur/ura | | doi/do | | trei | | pɒtru | |
| Europe and Asia | Indo-European | Selice Romani | jékh | | dúj | | trín | | štár | |

# Numerals: One–Four (Part B)

| Languages | | | Numerals | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Areas | L family | RL name | One | B vs I | Two | B vs I | Three | B vs I | Four | B vs I |
| South America | Creole | Saramaccan | wán | | tú | | dií | | fõ | |
| | | Saramaccan variants | | | | | | | | |
| Europe and Asia | Indo-European | Domari | ikak | | diyyes | | taranes | | štares | |
| | | Domari variants | | | | | | | | |
| Africa | Niger-Congo, Bantoid | Swahili | -moja | | -wili | | -tatu | | -ne | |
| Pacific | Austronesian | Takia | ksaek | | raru, uraru | | utol | | iwaiwo | |
| | | Takia variants | | | | | | | | |
| Africa | Afro-Asiatic, Berber | Tarifiyt Berber | iǧǧen | | tnayen | B, SL Classical Arabic | třata | B, SL Arabic (Moroccan, Classical) | ãbʕa | B, SL Arabic (Moroccan, Classical) |
| | | Tarifiyt Berber variants | ištən | | | | | | | |
| Africa | Afro-Asiatic, Berber | Ayt Ndhir | yun/yuṯ | | sin/snaṯ | | šraḍ šraṯ | | rbɛa | B, SL Arabic |
| Africa | Nilo-Saharan | Tasawak | fó | | hínká | | hínzà | | tãási | |
| | | Tasawak variants | a-f:ó | | à-hínká | | à-hínzà | | à-t:áási | |
| South America | isolate | Urarina | lejhia | | kuruata(ha)a | | niteatahaa | | heena | |

# Numerals: One–Four (Part C)

| Areas | L family | RL name | One | B vs I | Two | B vs I | Three | B vs I | Four | B vs I |
|---|---|---|---|---|---|---|---|---|---|---|
| Europe and Asia | Tai-Kadai | Thai | nɯŋ | | sɔ̌ɔŋ | | sǎam | B, SL Middle Chinese | sìi | B, SL Middle Chinese |
| | | Thai variants | ʔèek | B, SL Sanskrit | yîi | B, SL Middle Chinese | trii | B, SL Sanskrit | càtù | B, SL Pali/ Sanskrit |
| | | Thai variants | ʔèt (2) | | thoo | B, SL Sanskrit | tray | B, SL Sanskrit | càturá | B, SL Sanskrit |
| Europe and Asia | Sino-Tibetan | Yakkha | i | | hiC | | sum | | cǎr | B, SL Nepali |
| | | Yakkha variants | eko | B, SL Nepali | | | | | | |
| Europe and Asia | Sino-Tibetan | Rabha | gósa | | aniŋ | | antham | | cari | B, SL Assamese |
| Europe and Asia | Hmong-Mien | White Hmong | ib | | ob | | peb (2) | | plaub (2) | B, SL Tibeto-Burman |
| South America | Matacoan | Wichí | unu | B, SL Spanish | lus | B, SL Spanish | tales | B, SL Spanish | kwatlu | B, SL Spanish |
| South America | Tupian | Paraguayan Guaraní | peteĩ | | mokõi | | mbohapy | | irundy | |
| | | P. Guaraní variants | | | | | | | | |
| North and Central | Uto-Aztecan | Yaqui | wepulai | | woi | | baji | | naiki | |
| America | | Yaqui variants | uno | B, SL Spanish | los ~ dos | B, SL Spanish | tres | B, SL Spanish | kuatro | B, SL Spanish |
| Pacific | Austronesian | Rapa Nui | tahi | | rua | | toru | | hā | |
| | | Rapa Nui variants | ho'e | B, SL Tahitian | piti | B, SL Tahitian | | | maha | B, SL Tahitian |

# Numerals: Five–Eight (Part A)

| Languages | | | Numerals | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Areas | L family | RL name | Five | B vs I | Six | B vs I | Seven | B vs I | Eight | B vs I |
| Europe and Asia | Austroasiatic | Ceq Wong | limã? | B, SL Malay | nãm | B, SL Malay | tujoh | B, SL Malay | lapan | B, SL Malay |
| Europe and Asia | Austroasiatic, Munda | Bondo | moloi | | ʈiʔiri | | giʔ | | ʈomam | |
| Africa | Afro-Asiatic, West Chadic | Hausa | biyár̃ | | ono | | bákwài | | tákwàs | |
| South America | Nadahup | Hup | ʔayup d'apũ̃h | | céc | B, SL Portuguese | céci | B, SL Portuguese | ʔóytu | B, SL Portuguese |
| | | Hup variants | | | | | | | | |
| Europe and Asia | Japonic | Japanese | itsutsu | | roku | | nanatsu | | yattsu | |
| | | Japanese variants | go (1) | | | | nana | | hachi (3) | |
| | | Japanese variants | | | | | shichi | | | |
| Africa | Khoisan | Kwadi | tánù | B, SL Bantu | lʼɲàu | | láɲàu | | sébéɓółtɛxtɔpɛnɔ | |
| Europe and Asia | Indo-European | Molise Croatian | pet | | sèj | B, SL Italo-Romance | sèt | B, SL Italo-Romance | ôt | B, SL Italo-Romance |
| | | Molise Croatian variants | čing | B, SL Italo-Romance | | | | | | |
| Europe and Asia | Indo-European | Istro-Romanian (Northern) | činč | | šɒse | | šɒpte | | opt | |
| Europe and Asia | Indo-European | Selice Romani | pándž | | šó | B, SL Greek | efta | B, SL Greek | ofto | B, SL Greek |

# *Numerals: Five–Eight (Part B)*

| Languages | | | Numerals | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Areas | L family | RL name | Five | *B vs I* | Six | *B vs I* | Seven | *B vs I* | Eight | *B vs I* |
| South America | Creole | Saramaccan | féífi (2) | | síkísi | | séßén | | áíti | |
| | | Saramaccan variants | | | | | séßi | B, SL Sranan/Dutch | | |
| Europe and Asia | Indo-European | Domari | p/ʌndžes | | sitt-ēk-i | B, SL Arabic | sabʕ-ak-i | B, SL Arabic | tamāniy-ak-i | B, SL Arabic |
| | | Domari variants | | | | | | | | |
| Africa | Niger-Congo, Bantoid | Swahili | -tano | | sita | B, SL Arabic | saba | B, SL Arabic | -nane | |
| Pacific | Austronesian | Takia | kafe-n da | | siks | B, SL Tok Pisin/English | sabaen | B, SL Tok Pisin/English | eit | B, SL Tok Pisin/English |
| | | Takia variants | faif | B, SL Tok Pisin/English | | | | | | |
| Africa | Afro-Asiatic, Berber | Tarifiyt Berber | xəmsa | B, SL Arabic (Moroccan, Classical) | sətta | B, SL Arabic (Moroccan, Classical) | səbʕa | B, SL Arabic (Moroccan, Classical) | tmənya | B, SL Arabic (Moroccan, Classical) |
| | | Tarifiyt Berber variants | | | | | | | | |
| Africa | Afro-Asiatic, Berber | Ayt Ndhir | xəmsa | B, SL Arabic | sətta | B, SL Arabic | səbʕa | B, SL Arabic | ʈmanya | B, SL Arabic |
| Africa | Nilo-Saharan | Tasawak | xámsà | B, SL Arabic | síːà | B, SL Arabic | sábàyà | B, SL Arabic | támáɲ̀yà | B, SL Arabic |
| | | Tasawak variants | | | | | | | | |
| South America | isolate | Urarina | saukia | | sauta | B, SL Quechua | kãsi/kãasi | B, SL Quechua | hoosa/fwoosa | B, SL Quechua |

*Numerals: Five–Eight (Part C)*

| Languages | | | Numerals | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Areas | L family | RL name | Five | *B vs I* | Six | *B vs I* | Seven | *B vs I* | Eight | *B vs I* |
| Europe and Asia | Tai-Kadai | Thai | hâa | B, SL Old Chinese | hòk | B, SL Middle Chinese | cèt | B, SL Middle Chinese | pàeaet | B, SL Middle Chinese |
| | | Thai variants | bencà | B, SL Pali/Sanskrit | chòo | B, SL Pali | sàttà | B, SL Pali/Sanskrit | ʔàtsatà | B, SL Sanskrit |
| | | Thai variants | pancà | B, SL Pali/Sanskrit | | | | | | |
| Europe and Asia | Sino-Tibetan | Yakkha | pãc | B, SL Nepali | cʰʌ | B, SL Nepali | sãt | B, SL Nepali | ãʈh | B, SL Nepali |
| | | Yakkha variants | | | | | | | | |
| Europe and Asia | Sino-Tibetan | Rabha | pas | B, SL Assamese | soi | B, SL Assamese | sat | B, SL Assamese | at | B, SL Assamese |
| Europe and Asia | Hmong–Mien | White Hmong | tsib | | rau (3) | B, SL Tibeto-Burman | xya | | yim | B, SL Tibeto-Burman |
| South America | Matacoan | Wichí | sinku | B, SL Spanish | seis | B, SL Spanish | siete | B, SL Spanish | ocho | B, SL Spanish |
| South America | Tupian | Paraguayan Guaraní | po | | poteĩ | | pokõi | | poapy | |
| | | P. Guaraní variants | cinco | B, SL Spanish | seis | B, SL Spanish | siete | B, SL Spanish | ocho | B, SL Spanish |
| North and Central America | Uto-Aztecan | Yaqui | mamni | | busani | | wobusani | | wojnaiki | |
| | | Yaqui variants | sinko | B, SL Spanish | seis | B, SL Spanish | siete | B, SL Spanish | ocho | B, SL Spanish |
| Pacific | Austronesian | Rapa Nui | rima | | ono | | hitu | | va'u | B, SL Tahitian |
| | | Rapa Nui variants | pae | B, SL Tahitian | | | | | | |

*Numerals: Nine–Ten (Part A)*

| Languages | | | Numerals | | | | References |
|---|---|---|---|---|---|---|---|
| Areas | L family | RL name | Nine | *B vs I* | Ten | *B vs I* | |
| Europe and Asia | Austroasiatic | Ceq Wong | smilan | B, SL Malay | spuloh | B, SL Malay/Chinese | Kruspe (2009) |
| Europe and Asia | Austroasiatic, Munda | Bondo | no | B, SL Oriya | ḍọs | B, SL Oriya | Chan; Swain (1998: 393) |
| Africa | Afro-Asiatic, West Chadic | Hausa | tárà | | góomà | | Awagana et al. (2009) |
| South America | Nadahup | Hup | nɔ́wi | B, SL Portuguese | déc | B, SL Portuguese | Epps (2009) |
| | | Hup variants | | | d'apŭh nihũ´? | | Epps (2009) |
| Europe and Asia | Japonic | Japanese | kokonotsu | | tō (1) | | Schmidt (2009) |
| | | Japanese variants | kyū (2) | | jū (2) | | Schmidt (2009) |
| | | Japanese variants | | | | | Schmidt (2009) |
| Africa | Khoisan | Kwadi | móyò | B, SL Bantu | mólà | B, SL Bantu | Chan |
| Europe and Asia | Indo-European | Molise Croatian | nòv | B, SL Italo-Romance | dijàč | B, SL Italo-Romance | Breu (2013) |
| | | Molise Croatian variants | | | | | Breu (2013) |
| Europe and Asia | Indo-European | Istro-Romanian (Northern) | devet | B, SL Croatian | deset | B, SL Croatian | Loporcaro et al. (2021) |
| Europe and Asia | Indo-European | Selice Romani | eňňa | B, SL Greek | deš | | Elšík (2009) |

*Numerals: Nine–Ten (Part B)*

| Languages | | | Numerals | | | | |
| Areas | L family | RL name | Nine | B vs I | Ten | B vs I | References |
| --- | --- | --- | --- | --- | --- | --- | --- |
| South America | Creole | Saramaccan | néígi | | téni | | Good (2009) |
| | | Saramaccan variants | néni | | | | Good (2009) |
| Europe and Asia | Indo-European | Domari | tisʕ-ak-i | B, SL Arabic | das | | Matras (2012) |
| | | Domari variants | | | ʕašr-ak-i | B, SL Arabic | Matras (2012) |
| Africa | Niger-Congo, Bantoid | Swahili | tisa | B, SL Arabic | kumi | | Schadeberg (2009) and Versteegh (2010: 648) |
| Pacific | Austronesian | Takia | naen | B, SL Tok Pisin/ English | ten | B, SL Tok Pisin/English | Ross (2009) |
| | | Takia variants | | | | | Ross (2009) |
| Africa | Afro-Asiatic, Berber | Tarifiyt Berber | tsʕa | B, SL Arabic (Moroccan, Classical) | ʕəšrˁa | B, SL Arabic (Moroccan, Classical) | Kossmann (2009) |
| | | Tarifiyt Berber variants | | | | | Kossmann (2009) |
| Africa | Afro-Asiatic, Berber | Ayt Ndhir | tsaɛa | B, SL Arabic | eɛšra | B, SL Arabic | Kossmann (2013: 308–309) and Souag (2007) |
| Africa | Nilo-Saharan | Tasawak | tísàyà | B, SL Arabic | ɣàsárà | B, SL Arabic | Kossmann (2007: 84, 2009) and Chan |
| | | Tasawak variants | | | | | Kossmann (2007: 84, 2009) and Chan |
| South America | isolate | Urarina | iskõo | B, SL Quechua | (le=) teuŋka | B, SL Quechua | Olawsky (2006) |

# Numerals: Nine–Ten (Part C)

| Languages | | | Numerals | | | | References |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Areas | L family | RL name | Nine | *B vs I* | Ten | *B vs I* | |
| Europe and Asia | Tai-Kadai | Thai | káaw | B, SL Middle Chinese | sip | B, SL Middle Chinese | Suthiwan (2009) |
| | | Thai variants | nóp | B, SL Pali/Sanskrit | thôt | B, SL Pali/Sanskrit | Suthiwan (2009) |
| | | Thai variants | | | | | Suthiwan (2009) |
| Europe and Asia | Sino-Tibetan | Yakkha | nau | B, SL Nepali | das | B, SL Nepali | Schackow (2015) |
| | | Yakkha variants | | | | | Schackow (2015) |
| Europe and Asia | Sino-Tibetan | Rabha | noi | B, SL Assamese | dos | B, SL Assamese | Chan; Her et al. (2019), Joseph (2007: 397), passim |
| Europe and Asia | Hmong-Mien | White Hmong | cuaj | | kaum (2) | B, SL Tibeto-Burman | Ratliff (2009) |
| South America | Matacoan | Wichí | nwewe | B, SL Spanish | lyes | B, SL Spanish | Vidal and Nercesian (2009) |
| South America | Tupian | Paraguayan Guaraní | porundy | | pa | | Estigarribia (2017: 62, 2020: 99–101) |
| | | P. Guaraní variants | nueve | B, SL Spanish | diez | B, SL Spanish | Estigarribia (2017: 62, 2020: 99–101) |
| North and Central America | Uto-Aztecan | Yaqui | batani | | wojmamni | | Estrada Fernández (2009) |
| | | Yaqui variants | nueve | B, SL Spanish | dies | B, SL Spanish | Estrada Fernández (2009) |
| Pacific | Austronesian | Rapa Nui | iva | | ho'e 'ahuru; 'aŋahuru | B, SL Tahitian | Kieviet (2017: 147, 150) |
| | | Rapa Nui variants | | | ho'e 'ahuru | B, SL Tahitian | Kieviet (2017: 147, 150) |

Abbreviations: *B* borrowed, *I* inherited, *L* language, *RL* recipient language, *SL* source language. *NB* numbers in parentheses indicate tones

# References

Agrillo, C., Dadda, M., & Bisazza, A. (2007). Quantity discrimination in female mosquitofish. *Animal Cognition, 10*(1), 63–70. https://doi.org/10.1007/s10071-006-0036-5

Agrillo, C., Petrazzini, M. E. M., & Bisazza, A. (2014). Numerical acuity of fish is improved in the presence of moving targets, but only in the subitizing range. *Animal Cognition, 17*(2), 307–316.

Awagana, A., Ekkehard, W. H., & Löhr, D. (2009). Hausa vocabulary. In M. Haspelmath & U. Tadmor (Eds.), *World loanword database*. Max Planck Institute for Evolutionary Anthropology.

Baayen, R. H. (2008). *Analyzing linguistic data. A practical introduction to statistics using R*. Cambridge University Press.

Bakker, P., & Matras, Y. (Eds.). (2013). *Contact languages: A comprehensive guide (language contact and bilingualism 6)*. De Gruyter Mouton.

Blažek, V. (1999). *Numerals: Comparative-etymological analyses of numeral systems and their implications (Saharan, Nubian, Egyptian, Berber, Kartvelian, Uralic, Altaic and indo-European languages)* (opera Universitatis Masarykianae Brunensis, Facultas Philosophica 322). Masarykova Univerzita.

Brauwer, D., Jolien, W. D., & Brysbaert, M. (2008). The SNARC effect in the processing of second-language number words: Further evidence for strong lexico-semantic connections. *Quarterly Journal of Experimental Psychology, 61*(3), 444–458.

Breu, W. (2013). Zahlen im totalen Sprachkontakt: Das komplexe System der Numeralia im Moliseslavischen. In T. Reuther (Ed.), *Slavistische Linguistik 2012: Referate des XXXVIII. Konstanzer Slavistischen Arbeitstreffens in Tainach* (Wiener Slawistischer Almanach 72, pp. 7–34). Sagner.

Brysbaert, M., & Duyck, W. (2010). Is it time to leave behind the revised hierarchical model of bilingual language processing after fifteen years of service? *Bilingualism: Language and Cognition, 13*(3), 359–371.

Butterworth, B., Reeve, R., Reynolds, F., & Lloyd, D. (2008). Numerical thought with and without words: Evidence from indigenous Australian children. *Proceedings of the National Academy of Sciences, 105*(35), 13179–13184.

Cantlon, J. F. (2018). How evolution constrains human numerical concepts. *Child Development Perspectives, 12*(1), 65–71.

Cantlon, J. F., & Brannon, E. M. (2006). Shared system for ordering small and large numbers in monkeys and humans. *Psychological Science, 17*(5), 401–406.

Cantlon, J. F., & Brannon, E. M. (2007). Basic math in monkeys and college students. *PLoS Biology, 5*(12), e328.

Carey, S. (2009). *The origin of concepts* (Oxford series in cognitive development 3). Oxford University Press.

Chan, E. *Numeral systems of the world's languages*. https://mpi-lingweb.shh.mpg.de/numeral/

Christiansen, M. H., & Chater, N. (2008). Language as shaped by the brain. *Behavioral and Brain Sciences, 31*(5), 489–509.

Comrie, B. (2013). Numeral bases. In M. S. Dryer & M. Haspelmath (Eds.), *The world atlas of language structures online*. Max Planck Institute for Evolutionary Anthropology. http://wals.info

Corbett, G. G. (2012). *Features*. Cambridge University Press.

Cordes, S., Gelman, R., Gallistel, C. R., & Whalen, J. (2001). Variability signatures distinguish verbal from nonverbal counting for both large and small numbers. *Psychonomic Bulletin & Review, 8*(4), 698–707.

Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences, 24*(1), 87–114.

Cowan, N. (2010). The magical mystery four: How is working memory capacity limited, and why? *Current Directions in Psychological Science, 19*(1), 51–57.

Curnow, T. J. (2001). What language features can be 'borrowed'? In Alexandra Y. Aikhenvald & Robert M. W. Dixon (eds.), *Areal diffusion and genetic inheritance: Problems in comparative linguistics* (pp. 412–436). Oxford: Oxford University Press.

de Hevia, M. D. (2011). Sensitivity to number: Reply to Gebuis and Gevers. *Cognition, 121*(2), 253–255.

de Hevia, M.-D., & Spelke, E. S. (2009). Spontaneous mapping of number and space in adults and young children. *Cognition, 110*(2), 198–207.

de Hevia, M. D., Izard, V., Coubart, A., Spelke, E. S., & Streri, A. (2014). Representations of space, time, and number in neonates. *PNAS, 111*(13), 4809–4813.

Decarli, G., Paris, E., Tencati, C., Nardelli, C., Vescovi, M., Surian, L., & Piazza, M. (2020). Impaired large numerosity estimation and intact subitizing in developmental dyscalculia. *PloS One, 15*(12), e0244578.

Dehaene, S. (2011). *The number sense: How the mind creates mathematics* (2nd ed.). Oxford University Press.

Dehaene, S., & Mehler, J. (1992). Cross-linguistic regularities in the frequency of number words. *Cognition, 43*(1), 1–29.

Dehaene, S., Bossini, S., & Giraux, P. (1993). The mental representation of parity and number magnitude. *Journal of Experimental Psychology: General, 122*(3), 371–396.

Dryer, M. S. (2013a). Coding of nominal plurality. In M. S. Dryer & M. Haspelmath (Eds.), *The world atlas of language structures online*. Max Planck Institute for Evolutionary Anthropology. http://wals.info

Dryer, M. S. (2013b). Indefinite articles. In M. S. Dryer & M. Haspelmath (Eds.), *The world atlas of language structures online*. Max Planck Institute for Evolutionary Anthropology. http://wals.info

Dryer, M. S., & Haspelmath, M. (Eds.). (2013). *The world atlas of language structures online*. Max Planck Institute for Evolutionary Anthropology. http://wals.info

Duyck, W., & Brysbaert, M. (2004). Forward and backward number translation requires conceptual mediation in both balanced and unbalanced bilinguals. *Journal of Experimental Psychology. Human Perception and Performance, 30*(5), 889–906.

Duyck, W., & Brysbaert, M. (2008). Semantic access in number word translation: The role of crosslingual lexical similarity. *Experimental Psychology, 55*(2), 102–112.

Elšík, V. (2009). Selice Romani vocabulary. In M. Haspelmath & U. Tadmor (Eds.), *World loanword database*. Max Planck Institute for Evolutionary Anthropology.

Epps, P. (2009). Hup vocabulary. In M. Haspelmath & U. Tadmor (Eds.), *World loanword database*. Max Planck Institute for Evolutionary Anthropology.

Epps, P. (2013). Inheritance, calquing, or independent innovation? Reconstructing morphological complexity in Amazonian numerals. *Journal of Language Contact, 6*(2), 329–357.

Estigarribia, B. (2017). A grammar sketch of Paraguayan Guarani. In B. Estigarribia & J. Pinta (Eds.), *Guarani linguistics in the 21st century* (Brill's studies in the indigenous languages of the Americas 14) (pp. 7–85). Brill.

Estigarribia, B. (2020). *A grammar of Paraguayan Guarani*. UCL Press.

Everett, C. (2017). *Numbers and the making of us: Counting and the course of human cultures*. Harvard University Press.

Feigenson, L., Dehaene, S., & Spelke, E. (2004). Core systems of number. *Trends in Cognitive Sciences, 8*(7), 307–314.

Fernández, E., & Zarina. (2009). Yaqui vocabulary. In M. Haspelmath & U. Tadmor (Eds.), *World loanword database*. Max Planck Institute for Evolutionary Anthropology.

Fias, W. (2001). Two routes for the processing of verbal numbers: Evidence from the SNARC effect. *Psychological Research, 65*(4), 250–259.

Fischer, M. H., & Shaki, S. (2014). Spatial associations in numerical cognition—From single digits to arithmetic. *Quarterly Journal of Experimental Psychology, 67*(8), 1461–1483.

Frank, M. C., Everett, D. L., Fedorenko, E., & Gibson, E. (2008). Number as a cognitive technology: Evidence from Pirahã language and cognition. *Cognition, 108*(3), 819–824.

Franzon, F., Zanini, C., & Rugani, R. (2019). Do non-verbal number systems shape grammar? Numerical cognition and number morphology compared. *Mind & Language, 34*(1), 37–58.

Franzon, F., Zanini, C., & Rugani, R. (2020). Cognitive and communicative pressures in the emergence of grammatical structure: A closer look at whether number sense is encoded in privileged ways. *Cognitive Neuropsychology, 37*(5–6), 355–358.

Furman, T., & Rubinsten, O. (2012). Symbolic and non symbolic numerical representation in adults with and without developmental dyscalculia. *Behavioral and Brain Functions, 8*(55), 1–15.

Gallistel, C. R., & Gelman, R. (1992). Preverbal and verbal counting and computation. *Cognition, 44*(1–2), 43–74.

Galton, F. (1880). Visualised numerals. *Nature, 21*(543), 494–495.

Gardani, F. (2008). *Borrowing of inflectional morphemes in language contact*. Peter Lang.

Gardani, F. (2012). Plural across inflection and derivation, fusion and agglutination. In L. Johanson & M. I. Robbeets (Eds.), *Copies versus cognates in bound morphology* (pp. 71–97). Brill.

Gardani, F. (2018). On morphological borrowing. *Language and Linguistics Compass, 12*(10), e12302. [1–17].

Gardani, F. (2020a). Borrowing matter and pattern in morphology. An overview. *Morphology, 30*(4), 263–282.

Gardani, F. (2020b). Morphology and contact-induced language change. In A. Grant (Ed.), *The Oxford handbook of language contact* (pp. 96–122). Oxford University Press.

Gelman, R., & Butterworth, B. (2005). Number and language: How are they related? *Trends in Cognitive Sciences, 9*(1), 6–10.

Givón, T. (1981). On the development of the numeral 'one' as an indefinite marker. *Folia Linguistica Historica, 2*(1), 35–54.

Göbel, S. M., Shaki, S., & Fischer, M. H. (2011). The cultural number line: A review of cultural and linguistic influences on the development of number processing. *Journal of Cross-Cultural Psychology, 42*(4), 543–565.

Good, J. (2009). Saramaccan vocabulary. In M. Haspelmath & U. Tadmor (Eds.), *World loanword database*. Max Planck Institute for Evolutionary Anthropology.

Gordon, P. (2004). Numerical cognition without words: Evidence from Amazonia. *Science (New York, NY), 306*(5695), 496–499.

Green, C. (2017). Usage-based linguistics and the magic number four. *Cognitive Linguistics, 28*(2), 209–237.

Greenberg, J. H. (1978). Generalizations about numeral systems. In J. H. Greenberg, C. A. Ferguson, & E. A. Moravcsik (Eds.), *Universals of human language, volume 3: Word structure* (Vol. 3, pp. 249–295). Stanford University Press.

Gvozdanović, J. (Ed.). (1992). *Indo-European numerals* (Trends in linguistics. Studies and monographs [TiLSM] 57). De Gruyter Mouton.

Halberda, J., & Feigenson, L. (2008). Developmental change in the acuity of the "number sense": The approximate number system in 3-, 4-, 5-, and 6-year-olds and adults. *Developmental Psychology, 44*(5), 1457–1465.

Haspelmath, M., & Tadmor, U. (Eds.). (2009). *Loanwords in the world's languages: A comparative handbook*. De Gruyter Mouton.

Hauser, M. D., & Spelke, E. (2004). Evolutionary and developmental foundations of human knowledge: A case study of mathematics. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences III* (pp. 853–864). The MIT Press.

Her, O.-S., Tang, M., & Li, B.-T. (2019). Word order of numeral classifiers and numeral bases. *STUF – Language Typology and Universals, 72*(3), 421–452.

Hothorn, T., Buehlmann, P., Dudoit, S., Molinaro, A., & Van Der Laan, M. (2006). Survival ensembles. *Biostatistics, 7*(3), 355–373.

Hubbard, E. M., Diester, I., Cantlon, J. F., Ansari, D., van Opstal, F., & Troiani, V. (2008). The evolution of numerical cognition: From number neurons to linguistic quantifiers. *The Journal of Neuroscience, 28*(46), 11819–11824.

Hurford, J. R. (1987). *Language and number: The emergence of a cognitive system*. Basil Blackwell.

Hyde, D. C. (2011). Two systems of non-symbolic numerical cognition. *Frontiers in Human Neuroscience, 5*(150), 1–8.

Hyde, D. C., & Mou, Y. (2016). Neural and behavioral signatures of core numerical abilities and early symbolic number development. In D. B. Berch, D. C. Geary, & K. M. Koepke (Eds.), *Development of mathematical cognition: Neural substrates and genetic influences* (Mathematical cognition and learning 2) (pp. 51–77). Elsevier.

Hyde, D. C., & Spelke, E. S. (2011). Neural signatures of number processing in human infants: Evidence for two core systems underlying numerical cognition. *Developmental Science, 14*. http://onlinelibrary.wiley.com/doi/10.1111/j.1467-7687.2010.00987.x/full

Izard, V., Sann, C., Spelke, E. S., & Streri, A. (2009). Newborn infants perceive abstract numbers. *PNAS, 106*(25), 10382–10385.

Joseph, U. V. (2007). *Rabha*. Leiden & Boston.

Kaufman, E. L., Lord, M. W., Reese, T. W., & Volkmann, J. (1949). The discrimination of visual number. *The American Journal of Psychology, 62*(4), 498–525.

Kawai, N., & Matsuzawa, T. (2000). Numerical memory span in a chimpanzee. *Nature, 403*(6765), 39–40.

Kieviet, P. (2017). *A grammar of Rapa Nui* (Studies in diversity linguistics 12). Language Science Press.

Kossmann, M. (2007). Tasawaq. In Y. Matras & J. Sakel (Eds.), *Grammatical borrowing in cross-linguistic perspective* (pp. 75–89). Mouton de Gruyter.

Kossmann, M. (2009). Tarifiyt Berber vocabulary. In M. Haspelmath & U. Tadmor (Eds.), *World loanword database*. Max Planck Institute for Evolutionary Anthropology.

Kossmann, M. (2013). *The Arabic influence on northern Berber* (Studies in semitic languages and linguistics 67). Brill.

Kruspe, N. (2009). Ceq Wong vocabulary. In M. Haspelmath & U. Tadmor (Eds.), *World loanword database*. Max Planck Institute for Evolutionary Anthropology.

Landy, D. H., Jones, E. L., & Hummel, J. E. (2008). Why spatial-numeric associations aren't evidence for a mental number line. *Proceedings of the Annual Meeting of the Cognitive Science Society, 30*, 357–362.

Loporcaro, M., Gardani, F., & Giudici, A. (2021). Contact-induced complexification in the gender system of Istro-Romanian. *Journal of Language Contact, 14*(1), 72–126.

Martin, S. E. (2004). *A reference grammar of Japanese*. University of Hawai'i Press.

Matras, Y. (2007). The borrowability of structural categories. In Y. Matras & J. Sakel (Eds.), *Grammatical borrowing in cross-linguistic perspective* (pp. 31–73). Mouton de Gruyter.

Matras, Y. (2009). *Language contact* (Cambridge textbooks in linguistics). Cambridge University Press.

Matras, Y. (2012). *A grammar of Domari* (Mouton grammar library 59). De Gruyter Mouton.

McCrink, K., & Wynn, K. (2007). Ratio abstraction by 6-month-old infants. *Psychological Science, 18*(8), 740–745.

Nelson, T. M., & Bartley, S. H. (1961). Numerosity, number, arithmetization, measurement and psychology. *Philosophy of Science, 28*(2), 178–203.

Nieder, A. (2020). The adaptive value of numerical competence. *Trends in Ecology & Evolution, 35*(7), 605–617.

Notebaert, K., Nelis, S., & Reynvoet, B. (2011). The magnitude representation of small and large symbolic numbers in the left and right hemisphere: An event-related fMRI study. *Journal of Cognitive Neuroscience, 23*(3), 622–630.

Nuerk, H.-C., Iversen, W., & Willmes, K. (2004). Notational modulation of the SNARC and the MARC (linguistic markedness of response codes) effect. *The Quarterly Journal of Experimental Psychology Section A, 57*(5), 835–863.

Nuerk, H.-C., Wood, G., & Willmes, K. (2005). The universal SNARC effect: The association between number magnitude and space is amodal. *Experimental Psychology, 52*(3), 187–194.

Olawsky, K. J. (2006). *A grammar of Urarina* (Mouton grammar library 37). Mouton de Gruyter.

Piazza, M., Pinel, P., Le Bihan, D., & Dehaene, S. (2007). A magnitude code common to numerosities and number symbols in human intraparietal cortex. *Neuron, 53*. http://www.sciencedirect.com/science/article/pii/S0896627306009895

Pica, P., Lemer, C., Izard, V., & Dehaene, S. (2004). Exact and approximate arithmetic in an Amazonian indigene group. *Science, 306*(5695), 499–503.

Pitt, B., Ferrigno, S., Cantlon, J. F., Casasanto, D., Gibson, E., & Piantadosi, S. T. (2021). Spatial concepts of number, size, and time in an indigenous culture. *Science Advances, 7*(33), eabg4141.

Posid, T., & Cordes, S. (2015). The small–large divide. In D. Geary, D. B. Berch, & K. M. Koepke (Eds.), *Evolutionary origins and early development of number processing* (Mathematical cognition and learning 1) (Vol. 1, pp. 253–276). Elsevier.

R Core Team. (2020). *R: A language and environment for statistical computing.* R foundation for statistical computing. https://www.R-project.org/

Ramirez-Cardenas, A., & Nieder, A. (2019). Working memory representation of empty sets in the primate parietal and prefrontal cortices. *Cortex, 114*, 102–114.

Ratliff, M. (2009). White Hmong vocabulary. In M. Haspelmath & U. Tadmor (Eds.), *World loanword database*. Max Planck Institute for Evolutionary Anthropology.

Rinaldi, L., & Marelli, M. (2020). The use of number words in natural language obeys Weber's law. *Journal of Experimental Psychology: General, 149*(7), 1215–1230.

Roettger, T. B., & Domahs, F. (2015). Grammatical number elicits SNARC and MARC effects as a function of task demands. *Quarterly Journal of Experimental Psychology, 68*(6), 1231–1248.

Ross, M. (2009). Takia vocabulary. In M. Haspelmath & U. Tadmor (Eds.), *World loanword database*. Max Planck Institute for Evolutionary Anthropology.

Rugani, R. (2017). Towards numerical cognition's origin: Insights from day-old domestic chicks. *Philosophical Transactions of the Royal Society B: Biological Sciences, 373*, 20160509.

Rugani, R., & de Hevia, M.-D. (2017). Number-space associations without language: Evidence from preverbal human infants and non-human animal species. *Psychonomic Bulletin & Review, 24*(2), 352–369.

Rugani, R., & Regolin, L. (2020). Hemispheric specialization in spatial versus ordinal processing in the day-old domestic chick (*Gallus gallus*). *Annals of the New York Academy of Sciences, 1477*(1), 34–43.

Rugani, R., Vallortigara, G., & Regolin, L. (2013). Numerical abstraction in young domestic chicks (*Gallus gallus*). *PloS One, 8*(6), e65262.

Rugani, R., Vallortigara, G., Priftis, K., & Regolin, L. (2015). Animal cognition. Number-space mapping in the newborn chick resembles humans' mental number line. *Science, 347*(6221), 534–536.

Schackow, D. (2015). *A grammar of Yakkha* (Studies in diversity linguistics 7). Language Science Press.

Schadeberg, T. C. (2009). Loanwords in Swahili. In M. Haspelmath & U. Tadmor (Eds.), *Loanwords in the world's languages: A comparative handbook* (pp. 76–102). Mouton de Gruyter.

Schmidt, C. K. (2009). Japanese vocabulary. In M. Haspelmath & U. Tadmor (Eds.), *World loanword database*. Max Planck Institute for Evolutionary Anthropology.

Seiler, H. (1990). A dimensional view on numeral systems. In W. A. Croft, S. Kemmer, & K. Denning (Eds.), *studies in typology and diachrony: Papers presented to Joseph H. Greenberg on his 75th birthday* (Typological studies in language 20) (pp. 187–208). John Benjamins.

Shettleworth, S. J. (2010). *Cognition, evolution, and behavior* (2nd ed.). Oxford University Press.

Smets, K., Moors, P., & Reynvoet, B. (2016). Effects of presentation type and visual control in numerosity discrimination: Implications for number processing? *Frontiers in Psychology, 7*. Art 66.

Souag, L. (2007). The typology of number borrowing in Berber. In N. Hilton, R. Arscott, K. Barden, A. Krishna, S. Shah, & M. Zellers (Eds.), *Proceedings of the fifth University of Cambridge Postgraduate Conference in language research held on 20–21 march 2007* (pp. 237–244). Cambridge Institute of Language Research.

Spaepen, E., Coppola, M., Spelke, E. S., Carey, S. E., & Goldin-Meadow, S. (2011). Number without a language model. *Proceedings of the National Academy of Sciences of the United States of America, 108*(8), 3163–3168.

Spelke, E. S. (2000). Core knowledge. *American Psychologist, 55*(11), 1233–1243.

Starkey, P., & Cooper, R. G. (1995). The development of subitizing in young children. *British Journal of Developmental Psychology, 13*(4), 399–420.

Starr, A., Libertus, M. E., & Brannon, E. M. (2013). Number sense in infancy predicts mathematical abilities in childhood. *PNAS, 110*(45), 18116–18120.

Strobl, C., Boulesteix, A.-L., Zeileis, A., & Hothorn, T. (2007). Bias in random forest variable importance measures: Illustrations, sources and a solution. *BMC Bioinformatics, 8*. no. 25.

Strobl, C., Boulesteix, A.-L., Kneib, T., Augustin, T., & Zeileis, A. (2008). Conditional variable importance for random forests. *BMC Bioinformatics, 9*. no. 307.

Suthiwan, T. (2009). Thai vocabulary. In M. Haspelmath & U. Tadmor (Eds.), *World loanword database*. Max Planck Institute for Evolutionary Anthropology.

Swain, R. (1998). A grammar of Bonda language. *Bulletin of the Deccan College Research Institute, (58/59)*, 391–396

Tagliamonte, S. A., & Harald Baayen, R. (2012). Models, forests, and trees of York English: *Was/were* variation as a case study for statistical practice. *Language Variation and Change, 24*(2), 135–178.

Thomason, S. G., & Kaufman, T. (1988). *Language contact, creolization, and genetic linguistics*. University of California Press.

Tikhomirova, T., Kuzmina, Y., Lysenkova, I., & Malykh, S. (2019). The relationship between non-symbolic and symbolic numerosity representations in elementary school: The role of intelligence. *Frontiers in Psychology, 10*. Article 2724.

Trick, L. M., & Pylyshyn, Z. W. (1994). Why are small and large numbers enumerated differently? A limited-capacity preattentive stage in vision. *Psychological Review, 101*(1), 80–102.

Tzelgov, J., Ganor-Stern, D., Kallai, A., & Pinhas, M. (2015). Primitives and non-primitives of numerical representations. In R. C. Kadosh & A. Dowker (Eds.), *The Oxford handbook of numerical cognition* (pp. 45–66). Oxford University Press.

Vallortigara, G. (2012). Core knowledge of object, number, and geometry: A comparative and neural approach. *Cognitive Neuropsychology, 29*(1–2), 213–236.

Vallortigara, G, Chiandetti, C, Rugani, R, Sovrano, V. A., & Regolin, L. (2010). Animal cognition. Wiley Interdisciplinary Reviews. *Cognitive Science*, *1*(6), 882–893.

Versteegh, K. (2010). Contact and the development of Arabic. In R. Hickey (Ed.), *Handbook of language contact* (pp. 634–651). Blackwell.

Vidal, A., & Nercesian, V. (2009). Wichí vocabulary. In M. Haspelmath & U. Tadmor (Eds.), *World loanword database*. Max Planck Institute for Evolutionary Anthropology.

Winter, B., Matlock, T., Shaki, S., & Fischer, M. H. (2015). Mental number space in three dimensions. *Neuroscience and Biobehavioral Reviews, 57*, 209–219.

Wohlgemuth. (2009, January). *A typology of verbal borrowings* (trends in linguistics. Studies and monographs 211). Mouton de Gruyter.

Woodin, G., Winter, B., Perlman, M., Littlemore, J., & Matlock, T. (2020). 'Tiny numbers' are actually tiny: Evidence from gestures in the TV news archive. *PloS One, 15*(11), e0242142.

Wynn, T., Coolidge, F. L., & Overmann, K. A. (2013). The archaeology of number concept and its implications for the evolution of language. In R. P. Botha & M. Everaert (Eds.), *The evolutionary emergence of language: Evidence and inference* (Oxford studies in the evolution of language 17) (pp. 118–138). Oxford University Press.

Zhou, Kevin & Claire Bowern. 2015. Quantifying uncertainty in the phylogenetics of Australian numeral systems. *Proceedings Biological Sciences, 282*(1815).