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On the subitizing effect in language contact

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 2009), and it has been observed that high and more abstract numerals are more prone to borrowing than lower numerals (Matras 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 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

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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 language. Almost all languages of the world have number words, but they vary considerably with respect to how they encode numerosity¹ and which quantities they encode: some languages have an unlimited number of terms for quantities; others, such as some Australian (Zhou & Bower 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 Section 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

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”.

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 Section 5.3. Section 6 concludes the article.

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 to master 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; Agrillo et al. 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 such the 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 & 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 to 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 say 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 non-verbal 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 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).

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).

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 Mundurucu community in the Tapajós River basin and Spaepen et al. 2011 on the Nicaraguan homesigners). The reverse perspective, 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 Section 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 the access to the symbolic system such as the verbal representation of numerosity in language can imply the 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 & 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 also grammatical number is 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 & 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). 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 & 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 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 Section 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

³ It is worth noticing that there is no consensus on the phylogenetic 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).

different languages, Rinaldi & 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 (Section 2)—. This system is indeed ratio-dependent: as the ratio between the numbers to be discriminated increases, response times decrease, and accuracy increases. Rinaldi & 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 & 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’).

Eventually, Franzon et al. (2019, 2020) argued that nonverbal numerical cognition also shapes grammatical number. The authors provided typological and neuropsychological 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 in *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 a 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 raking for numerals for “0” is closer to the 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 still, 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. Section 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 (Section 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 also the different behavior of low vs high cardinal numerals in language contact is 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 been also 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 (Section 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 & 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 (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 models⁴ 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 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

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.

(yes/no) as 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.

	ONE	TWO	THREE	FOUR	FIVE	SIX	SEVEN	EIGHT	NINE	TEN
Σ forms	33	31	30	32	33	28	31	29	30	32
Σ 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

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

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.

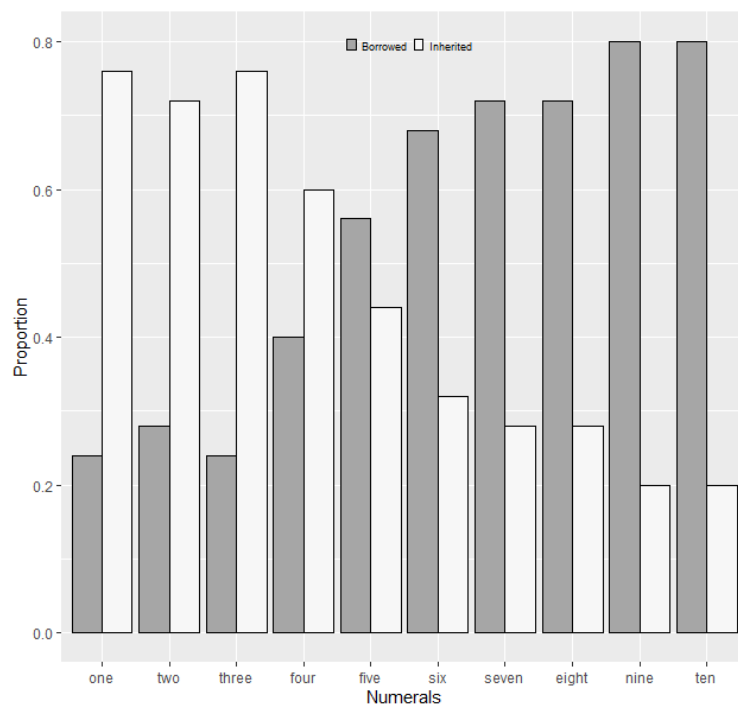


Figure 1: Proportion of all borrowed (in dark gray) and all inherited (in light gray) forms across numerals.

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.

	ONE	TWO	THREE	FOUR	FIVE	SIX	SEVEN	EIGHT	NINE	TEN
Σ borrowed	6	8	8	12	16	18	19	19	21	21
Σ 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

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

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 Figure 2.

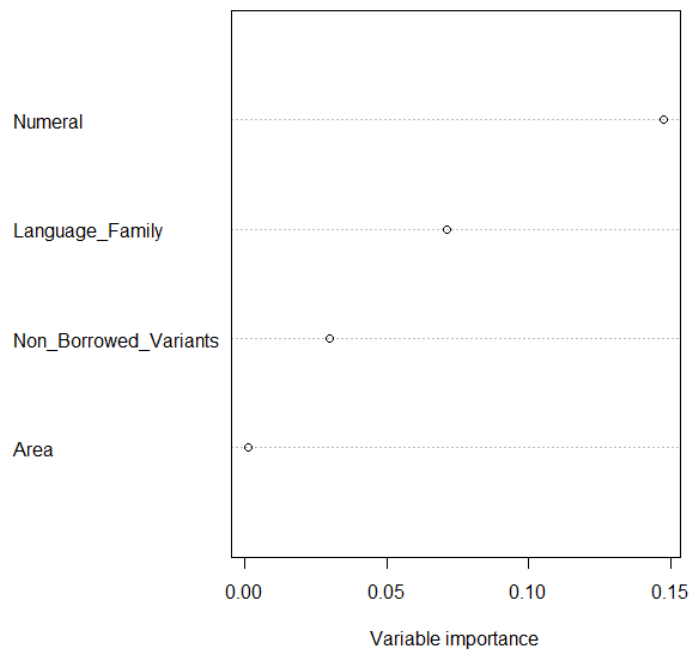


Figure 2: Conditional permutation importance of variables in the occurrence of borrowed vs inherited numerals.

Eventually, 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 Figure 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, 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 C is an index of the goodness of fit of the model. A C greater than 0.8 indicates that the model discriminates well.

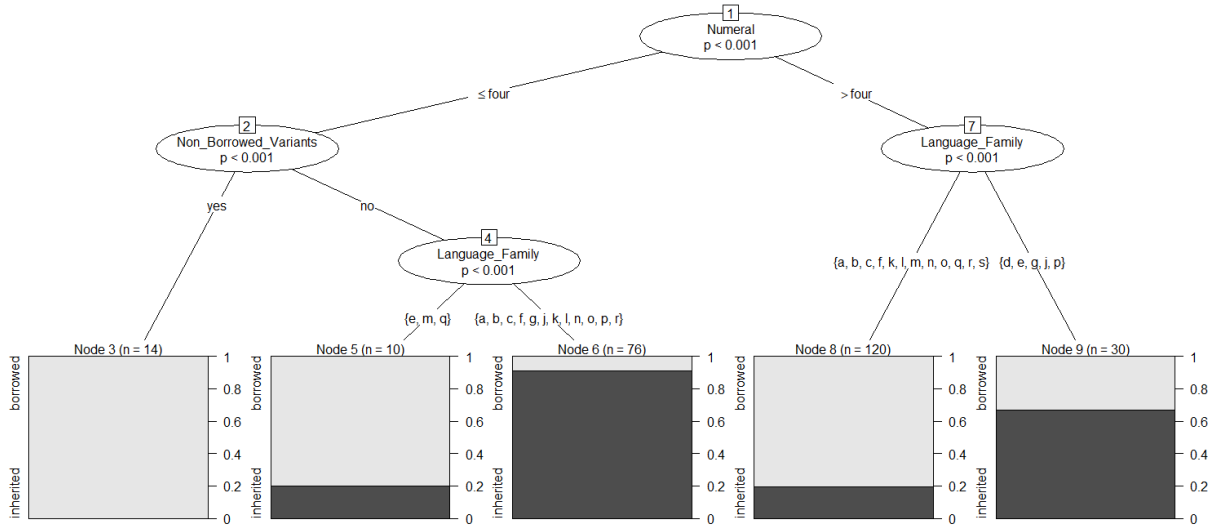


Figure 3: Conditional inference tree of the occurrence of borrowed vs inherited numerals. The variables selected for the best split and the corresponding p -values are circled; the branches specified the levels of the variables; the bar plots at the bottom illustrate the proportion of inherited forms (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).

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 Table 1 and 2 can be explained in terms of the hypothesis we made in Section 3 and Section 4, they can be just as well accounted for by the sociocultural explanation predominant in the literature (cf. Section 1). However, a clear clue that our cognition-based threshold hypothesis is superior comes from the statistical analysis we performed. The trees method allows 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 informed also 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 at 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, as 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 Section 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 on 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.

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Europe and A: Hmong-Mien White Hmong		ib	ob	peb (2)	plaub (2)	B, SL Tibeto- tsib	rau (3)	B, SL Tibeto- xya	yim	B, SL Tibeto- cuaj	kaum (2)	B, SL Tibeto-Burman	Ratliff 2009
South America: Matacoan	Wichí	unu	B, SL Spanisl lus	B, SL Spanisl tales	B, SL Spanisl kwatlu	B, SL Spanisl sinku	B, SL Spanisl seis	B, SL Spanisl siete	B, SL Spanisl ocho	B, SL Spanisl nwewe	B, SL Spanisl lyes	B, SL Spanislh	Vidal & Neresian 2009
South America: Tupian	Paraguayan Guaraní	peteĩ	mokõi	mbohapy	irundy	po	peteĩ	pokõi	poapy	porundy	pa		Estigarribia 2017: 62, 2020: 99-101
						cinco	B, SL Spanisl seis	B, SL Spanisl siete	B, SL Spanisl ocho	B, SL Spanisl nueve	B, SL Spanisl diez	B, SL Spanislh	Estigarribia 2017: 62, 2020: 99-101
North and Cer Uto-Aztecan	Yaqui	wepulai	wot	baji	naiki	mamni	busani	wobusani	wojnaiki	batani	wojmamni		Estrada Fernández 2009
		Yaqui: variants	uno	B, SL Spanisl los ~ dos	B, SL Spanisl tres	B, SL Spanisl cuatro	B, SL Spanisl sinko	B, SL Spanisl seis	B, SL Spanisl siete	B, SL Spanisl ocho	B, SL Spanisl nueve	B, SL Spanisl diez	B, SL Spanislh
Pacific	Austronesian	Rapa Nui	tahi	rua	toru	hā	rima	ono	hitu	va'u	B, SL Tahitia iva	ho'e 'ahuru; 'u	B, SL Tahitian
		Rapa Nui: variants	ho'e	B, SL Tahitia piti	B, SL Tahitian	maha	B, SL Tahitia pae	B, SL Tahitian				ho 'e 'ahuru	B, SL Tahitian
			ONE	TWO	THREE	FOUR	FIVE	SIX	SEVEN	EIGHT	NINE	TEN	
Σ RIs	25												
Σ forms		33	31	30	32	33	28	31	29	30	32		
Σ borrowed		6	8	8	12	16	18	19	19	21	21		
Σ borrowed of which variants		5	6	4	6	8	4	4	4	4	6		
borrowed:total %		18.18	25.80	26.66	37.5	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	0.7	0.65		

Abbreviations: B borrowed; I inherited; L language; RL recipient language; SL source language. NB: Numbers in parentheses indicate tones.