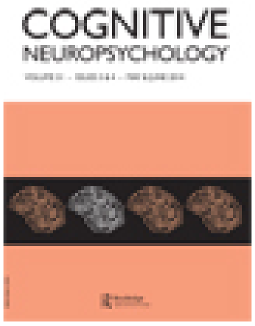

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Is native quantitative thought concretized in linguistically privileged ways? A look at the global picture

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ABSTRACT
This work investigates whether reference in speech to certain quantities, namely 1, 2, and 3, is privileged linguistically due to our brain's native quantitative capacities. It is suggested that these small quantities are not privileged in specific ways suggested in the literature. The case that morphology privileges these quantities, apart from 1, is difficult to maintain in light of the cross-linguistic data surveyed. The grammatical expression of 2 is explained without appealing to innate quantitative reasoning and the grammatical expression of 3 is not truly characteristic of speech once language relatedness is considered. The case that 1, 2, and 3 are each privileged lexically is also difficult to maintain in the face of the global linguistic data. While native neurobiological architecture biases humans towards recognizing small quantities in precise ways, these biases do not yield clear patterns in numerical language worldwide.

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1. Introduction and background

The phylogenetically primitive native "number sense", housed in part in the intraparietal sulcus, enables the abstract and approximate discrimination of large quantities while also enabling the subitization and exact discrimination of small quantities (Cantlon, 2011; Dehaene, 2011). Humans have the native abilities to differentiate small quantities like 1, 2, and 3 precisely, and to differentiate larger quantities from each other in a coarse manner (Dehaene, 2011; Izard, Sann, Spelke, & Streri, 2009, *inter alia*). While the relationship between, and the aetiology of, these quantity-discrimination abilities remains a matter of debate, their existence across human populations is generally agreed upon (For one recent survey, see Núñez, 2017.). Whether one considers humans' native exact discrimination of 1, 2, and 3 to be due to our "object file" system for keeping track of three entities simultaneously, or due to the relative ease of differentiation of quantities characterized by pronounced ratios like 3:1, 2:1, and 3:2, robust evidence has demonstrated that these three quantities are privileged in human thought (Carey, 2009; Dehaene, 2011). This has even been demonstrated amongst cultures that lack the numerical language or other symbols for exact quantities (Everett & Madora, 2012; Frank, Everett, Fedorenko, & Gibson, 2008; Pica, Lemer, Izard, & Dehaene, 2004; Spaepen, Coppola, Spelke, Carey, & Goldin-Meadow, 2011).

Rafael Núñez has recently argued that it would be more accurate to claim that humans are natively equipped with the capacity for "quantical" reasoning, but not, strictly speaking, "numerical" reasoning or a "number sense" (Núñez, 2017; for a very similar suggestion see Everett, 2017, p. 256). Núñez suggests humans are born with a capacity for generally fuzzy quantical reasoning (that allows for the exact discrimination of 1, 2, and 3, only) but that truly numerical reasoning is the byproduct of particular cultural and linguistic traditions using number symbols, verbal and/or written. Núñez's terminological choice is adopted here, as it helps to clarify the distinction between those concepts that are given to us through innate mechanisms (quantical concepts) from those that are not (numerical concepts), without conflating them under the imprecise rubric of "numerical". As Núñez points out, the common tack of referring to both native quantical concepts and culturally evolved numerical concepts as "numerical" or "numbers" is problematic in that, *inter alia*, such a terminological choice does not allow us to easily distinguish innate quantity-discrimination abilities, shared by multiple species, from those

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quantity-discrimination abilities that are only evident in human cultures that have innovated or adopted numerical technologies including number words like "seven". In the words of Núñez:

> Quantical cognition is biologically endowed, but numerical cognition is not. Quantical cognition may be the manifestation of biologically evolved preconditions for numerical cognition and arithmetic, but is itself not about number or arithmetic … Crucially, quantical cognition does not, by itself, scale up to produce number and arithmetic. (2017, p. 419)

In the light of Núñez's terminological suggestion, adopted henceforth, we might suspect that human quantical capacities have a clear impact on numerical language across the world's cultures. In fact, this suspicion has resulted in specific claims that native quantitative concepts are treated in linguistically privileged ways—that is, that the world's languages treat these concepts in a special and predictable fashion when contrasted to the manner in which they treat other quantitative concepts. This work is an exploration of some of these specific claims and, more broadly, is an exploration of the way in which the precise quantities of 1, 2, and 3 are linguistically concretized in the world's languages.

To presage the findings: The evidence proffered in this study suggests that quantical concepts are not actually concretized in linguistically privileged ways, or at least not in some of the privileged ways that have been hypothesized in the literature. These quantical concepts are not treated in predictable and special ways by the world's languages, when contrasted to other quantitative concepts like 4 and 5. For instance, as we will see below it has been suggested that words like "one", "two", and "three" are predictably ubiquitous and ancient across the world's languages, when contrasted to other number words. This claim is not clearly supported, however. Instead, the linguistic instantiation of such quantical concepts is sculptable in culturally contingent ways as detailed below, ways that characterize other kinds of words that have no putatively special or ancient status. While the cultural sculpting of higher number words has long been known, the pervasive cultural shaping of words for 1, 2, and 3, is perhaps less expected—particularly in the light of some related claims in the literature discussed below. This sculpting further calls into question the suggestion that such native quantical concepts are privileged grammatically or lexically. There is evidence that 1 is linguistically privileged. But there is no strong evidence that 2 and 3 are privileged. To be clear, the findings presented in this exploration are not meant to serve as evidence against the well-established claim that humans can natively discriminate 1, 2, and 3 precisely. Nevertheless, the fact that these native concepts are not linguistically privileged is incompatible with some ideas in the literature. The lack of clear linguistic privileging of quantical concepts, at least as it relates to 2 and 3, may merit further exploration and clearer incorporation into some theoretical models on quantitative cognition.

2. Are quantical concepts grammatically privileged?

Superficially, there does appear to be a parallel between quantical cognition and grammatical number: Some grammars discriminate 1 from all other quantities (singular vs. plural/paucal), some differentiate 1, from 2, from all other quantities (singular, dual, and plural/paucal), and some distinguish 1, from 2, from 3, from all other quantities (singular, dual, trial, and plural/paucal). Given how many numerical distinctions are possible, and given that there are over 7000 languages (Simons, 2017), it might seem reasonable to expect that some languages use grammatical number to make precise quantitative distinctions beyond these. Why don't they? According to one recent account, the typological restrictions on grammatical number directly reflect the shared neurobiology of human populations since quantical cognition is "reflected as a core part of language" (Franzon, Zanini, & Rugani, 2018). More specifically, the authors of the study in question suggest the following:

> We propose that a parallelism exists between expressible information with Number morphology *throughout natural languages* and information processed by the two non-verbal numerical systems, namely, the OFS [object file system] and the AMS [analogue magnitude system]. Furthermore, we suggest that grammar is a domain wherein Number morphology and non-verbal numerical systems interact, sharing some common evolved neurocognitive mechanisms. (emphasis added)

The majority of languages do display morphological devices for encoding quantity, namely 1 (singular) vs. other quantities (plural). However, Franzon et al.'s

(2018) relevant claim is stronger and more precise. They observe that grammars are limited to exact number distinctions for 1, 2, and 3, and suggest this typological limitation on grammatical number meaningfully reflects an interaction between "common evolved neurocognitive mechanisms" for grammar and quantical thought. In short, the limitations of grammatical number types is putatively due to deep-seated neurocognitive factors and not readily explainable by other phenomena. Yet this limit is quite likely explainable by usage-based factors, as suggested below. Additionally, the supposed linguistic limit in question, 3, is not really evident once language family and region are considered. Instead, languages are best considered to be limited to encoding precisely 1 and perhaps 2 with their grammars. Grammatical trials are not just rare, they are only really attested in one language family—less attested than countless grammatical phenomena for which we would not posit the relevance of universal biases. Furthermore, a case can be made that the limit requiring actual explanation is 1, since it is systematically evident as a limit across the world's language families and since the singular/plural distinction is utilized to describe basic quantitative distinctions associated with all things and action types, rather than being severely limited in function. The world's "dual" grammatical markers, on the other hand, are much more restricted in terms of both cross-linguistic frequency and functional utility. (Corbett, 2000)

In support of their account, Franzon et al. (2018) surveyed grammatical number in 218 languages. These 218 languages represent 50 different language families and 8 language isolates. Their survey demonstrates that, for instance, there are no languages that refer to quantities like 5 or 6 grammatically. On the other hand, the vast majority of languages surveyed have a singular vs. plural distinction ($n = 214$). And, according to their survey, a significant number of languages have a grammatical dual marker, with this feature attested in 84 of the languages considered. Finally, Franzon et al. (2018) note that the only other sort of clearly attested grammatical number category that refers to a specific quantity is trial. While they acknowledge the rarity of grammatical trial markers, they observe that such markers are found in 20 of the 218 languages surveyed. Even judging from these figures alone, one wonders why duals are absent in so many languages, and why trials so incredibly uncommon, if "shared neurocognitive mechanisms" explain similar patterns in quantical thought and grammatical number. To be fair, these shared mechanisms putatively explain only the observable *limit* of 3 in precise grammatical number categories, and do not necessarily predict the commonality of grammatical number categories in the world's languages. But there is a key point glossed over in such a claim: Grammatical trial is restricted to Oceania, and is only clearly attested in Austronesian language stocks or Austronesian based creoles (Corbett, 2000). It is very much a regional feature, or more accurately a subregional feature. From a typological perspective, the trial is not significantly more well attested than the nonexistent "quintal" or "sextal". If a linguistic feature can be traced to one language family in one world region, it cannot be claimed to be generally characteristic of human language just because some other theoretically possible feature (like quintal) is attested in zero families. The distribution is likely coincidental, contingent on a particular cultural innovation that is possibly unrelated to the phenomena that generally drive the evolution of grammatical number. In short, the evidence that 3 truly serves as an observable or meaningful limit for precise grammatical number is very weak. Were we to choose to consider phenomena exhibited by single language families as being critical to our understanding of native neurocognitive mechanisms, the list of phenomena that would immediately become relevant to our understanding of universal neurocognitive architecture would grow exponentially and include many linguistic features that have clearly local and culturally contingent origins. Franzon et al. (2018) stress an implicational claim first made in Greenberg (1963): "No language has a trial number unless it has a dual. No language has a dual unless it has a plural." This implicational is true, strictly speaking, but is also somewhat vacuous since trial only developed independently once judging from the comparative linguistic record.

It is actually unclear that grammatical trial should even be grouped as the same phenomenon as the singular grammatical number category evident in most languages. While grammatical singular is used to refer to pronouns, it does not do so exclusively and can refer to countless entity types in many languages. In those rare cases in which trial is attested at all, its functions are severely limited. In fact, cases of grammatical trial are essentially restricted to pronoun systems with distinctions akin to "you", "you two", and "you three" (Corbett, 2000). Grammatical trial is not used to distinguish, say, two trees from three trees, or one pig from three pigs. This seems puzzling if the grammatical distinction is directly related to limits in native quantical thought. Instead, grammatical trial seems to reflect a unique development in one pronominal paradigm in one ancestral language. This is a different phenomenon than, for instance, English singular and plural markers that can be used to categorize the number of a limitless assortment of entities.

While the grammatical dual is much more common than the trial, it is also often restricted in terms of function. Franzon et al. (2018) use the following example from the Sikuani language, taken from Aikhenvald (2014): *emairibü* "a yam" vs. *emairibü-nü* "yams" vs. *emairibü-behe* "two yams". The grammatical dual is used to distinguish the quantities of inanimate objects in some languages like Sikuani and Arabic. Yet it is often restricted, in those languages in which it occurs, to pronouns. This is true, for instance, in many Austronesian languages (Corbett, 2000). In other words, dual markers are often the specific result of grammaticalization processes in a highly frequent set of words, pronouns. The grammaticalization of the dual distinction is best construed in such cases as the result of the common need to refer to two first or second person referents in conversation. Grammatical categories generally arise when frequent "lexical items and constructions come in certain linguistic contexts to serve grammatical functions, and, once grammaticalized, continue to develop new grammatical functions". (Hopper & Traugott, 2003, p. 1) Functionally, one can see why the communicative need to distinguish 1, 2, and 3 interlocutors (especially 1 and 2) would be much more common in discourse than the need to refer to, for instance, exactly four or five interlocutors. This tells us something about how conversation typically works (and particularly about distinctions that have become relevant in conversations in Austronesian languages), not necessarily something about how quantical thought works. The fact that duals are so frequently pronominal and that trials are pronominal without exception suggests their diachronic sources are in most cases due to readily explainable discourse pressures. While the suggestion of Franzon et al. (2018) is quite reasonable (see also Dehaene, 2011, p. 80 and my own work, Everett, 2017, p. 102, for similar claims), there is really no need to appeal to shared neurocognitive mechanisms between grammar and quantical thought in order to explain the presence of trials in the few cases in which they are attested, and of the duals in many attested cases. In fact, such an appeal may distract from what the linguistic data are actually suggesting. Framed differently: Even if humans possessed quantical thought enabling the exact discrimination of precisely five items, we would not expect a grammatical "quintal" to develop in pronoun paradigms because the utility and discourse-based frequency of that distinction would be very limited. Conversely, it is inappropriate to rely on the grammaticalization of much more useful and discourse-frequent distinctions in pronouns (like whether there are one or two interlocutors present) to tell us something about quantical thought. One could interpret the mere existence of a grammatical trial as reflecting the limits of precise quantical thought, but this seems a problematic strategy. Instead, based on the cross-linguistic data alone, the more straightforward conclusion is simply that patterns of grammatical number reflect patterns in language usage without revealing much about quantical thought (excepting, perhaps, that humans are natively adept at distinguishing 1 from other quantities).

Also, it is interesting to note that the dual has been lost to diachronic processes in some well-documented cases. For instance, while Proto-Indo-European had a grammatical dual, most of its descendant languages do not. If "shared neurocognitive mechanisms" biased Proto-Indo-European speakers to use a grammatical dual, why were those neurocognitive biases insufficient to maintain it? In contrast, linguistic phenomena associated with discourse pressures are well known to grammaticalize and, in many cases, subsequently disappear from the grammars in which they appeared (Hopper & Traugott, 2003).

What the typological data suggest most strongly is that robust grammatical number phenomena, which are not idiosyncratically explainable by the need to describe the number of people typically associated with a speech event, are confined largely to the singular vs. plural distinction. The cross-linguistic dominance of the singular vs. plural distinction is evident in Franzon et al.'s (2018) data but is more clearly evident in larger surveys of grammatical number. For instance, out of 1066 languages surveyed in Dryer

(2013), 968 have a grammatical plural marker to distinguish the quantity of nominal referents, alongside a singular category. (These plural markers usually take the form of suffixes as in English ($n = 513$), but also prefixes ($n = 126$) and other forms like tonal markers ($n = 4$), according to the data in Dryer, 2013.) Almost 10% of the languages in Dryer's survey lack a grammatical number marker, making such languages more common than languages with grammatical dual or trial markers. Still, Franzon et al. (2018, p. 3) are correct when they state that the "relevance of the information about numerosity is such that the majority of languages display grammatical devices for its ready encoding and decoding".

The absence of a grammatical trial is also characteristic of a phenomenon not mentioned in most discussions of this topic: verbal number. While grammatical number typically refers to the quantity of nominal referents, in rarer cases it refers to verbal referents, i.e., the quantity of actions. For instance, in Mupun there is verb meaning "to hit", but a different verb meaning "to hit multiple times" or "hit over and over" (Veselinova, 2013). In a survey of 193 languages, Veselinova (2013) observes that verbal grammatical number is unattested in 159 languages. In 27 of the 34 languages in which it is attested, it is used to distinguish one action from multiple actions. In 7 of the 34 languages, it is used to distinguish 1 vs. 2 vs. multiple actions. Critically, none of the languages surveyed have a verbal grammatical trial. Here again, then, it would appear that the typical limit to the precise quantities referred to via grammatical number is 1, though strictly speaking the limit is 2. Yet it is apparently not 3.

The cross-linguistic data suggest that grammatical number is generally explainable without appealing to shared neurocognitive mechanisms, at least as it relates to the precise quantities of 2 and 3. To be clear, the suggested relationship seems a reasonable one and there are some imaging data supporting the relevance of the intraparietal sulcus to the processing of grammatical number. Carreiras, Carr, Barber, and Hernández (2010) observed increased activation in that cortical region when participants read noun phrases with grammatical number violations, but these violations related to the singular/plural distinction. Whether such imaging data would reveal similar patterns for grammatical trial and dual violations is unknown at present.

A look at the typological data on grammatical number leads us to questions like these: Why are languages so heavily biased to distinguish singular vs. plural referents, while paying negligible attention to the other concepts associated with quantical cognition? Why is there an exponential drop-off between singular/plural systems and all other systems, both in terms of range of use and range of occurrence cross-linguistically? Franzon et al. (2018) propose that "Number morphology has evolved in natural languages in order to efficiently encode information about a core cognitive feature, namely, the numerosity of entities. New research questions arise from this observation." In the light of the cross-linguistic distribution of grammatical number types, one could alternatively question why number morphology has evolved in a way that inefficiently encodes a core cognitive feature, or why it only efficiently encodes a subset of the quantities we are natively predisposed to recognize. Framed differently: a linguistic typologist surveying the world's systems of grammatical number might conclude that 1 is a native and universal concept, but would have no real evidence to conclude that the human brain is limited to precisely distinguishing 1 *and* 2 *and* 3. The "common evolved neurocognitive mechanisms" for quantity discrimination and grammatical number are largely opaque to cross-linguistic analysis. Of course one could still maintain that only quantical concepts surface in grammar, even if some quantical concepts only surface very rarely. However, this is somewhat of a tautological tack, unfalsifiable unless some languages are documented to have, say, a grammatical "sextal". There are various communicative reasons such a feature would be very unlikely to develop in the world's languages, apart from what we know about quantical thought. Such a tack also glosses over the fact that the grammatical encoding of 3 is not truly an attested strategy in the world's languages. It is only evident in one language family, and in one semantic domain in that family. It is less characteristic of speech than a complete lack of number words, evident in at least two language families, and a complete lack of grammatical number, evident in many families (Hammarström, 2010; Dryer, 2013). Returning to the unattested grammatical "sextal": Imagine such a feature did exist, but in only one language family and associated with only one communicative function—describing quantities of beer cans and other beverages, for example. The feature would likely be judged irrelevant to the understanding of native quantical thought, and with good reason.

3. Are quantical concepts lexically privileged?

Influential work has claimed that 1, 2, and 3 have a privileged lexical status in the world's languages, due to the universal and native biases of human quantitative thought. Consider the following claims made by Dehaene (2011, p. 80):

> When our species first began to speak, it may have been able to name only the numbers 1, 2, and perhaps 3. Oneness, twoness, and threeness are perceptual qualities that our brain computes effortlessly without counting. Hence, giving them a name was probably no more difficult than naming any other sensory attribute, such as red, big, or warm.

Dehaene suggests that this effortless processing of, and therefore easy naming of, oneness, twoness, and threeness is evidenced by the "antiquity and special status of the first three number words". (2011, p. 80) In support of this he notes, for instance, the distinct status of ordinal small numbers such as *first*, *second*, and *third*, when contrasted to regular ordinals like *fourth*, *fifth*, *sixth*, etc. … This is further buttressed by similar observations on the special treatment of words for 1, 2, and 3 in a variety of languages, as described in Hurford (1987). The examples offered by Hurford and Dehaene are taken from English, German, Greek, Italian, French, Latin, Welsh, and Latin. Note, however, that these languages are all descendants of Proto-Indo-European, and this general claim about numerical language still requires corroboration from a reasonable sample of the world's 300+ language families (Bickel & Nichols, 2017). In general, claims of universally motivated patterns in the world's languages require carefully sampled evidence that control for language relatedness and contact, or Galton's problem (Roberts & Winters, 2013). The data mentioned by Hurford and Dehaene suggest that 1, 2, and 3 were the first number words developed in Proto-Indo-European. Though Dehaene also observes that these words in Proto-Indo-European were imprecise, he suggests this ancient status is telling. Interestingly, Proto-Indo-European also had a precise dual. As noted in the preceding section, grammatical duals are found in only a small subset of the world's languages, so one straightforward interpretation of these findings is simply that Indo-European languages have inherited an ancient distinct linguistic treatment of 1, 2, and 3. That treatment is not a good indicator, necessarily, of the treatment evident in most languages.

There is in fact evidence that number words are ancient in at least three families, and that they are unlikely to be replaced over time when compared to other word types. Pagel and Meade (2018) offer evidence from Indo-European, Bantu, and Austronesian that number words are much less likely to be replaced in these languages when contrasted to other basic word types. In fact, according to Pagel and Meade, number words last between 3.5 and 20 times longer than other basic vocabulary items, before they are replaced in a given language. Yet the data in Pagel and Meade (2018), like those presented here, are also not consistent with the suggestion that 1, 2, and 3 have a privileged lexical status when contrasted to other number words. And that is the sort of linguistic privileging being investigated here: Are these native quantical concepts treated in special ways when compared to other numerical concepts that are constructed via culturally contingent scaffolding? Apparently not. For example, while Pagel and Meade's evidence for the "deep history of number words" suggests that "two" and "three" are the words that are least likely to be replaced over time in Indo-European, their data also suggest that "four" and "five" are less likely to be replaced than "one". The latter point also holds for Austronesian. Even more puzzlingly, in Bantu "four" and "five" are more slowly replaced over time than "one" and "two", so the words for the higher quantities are generally more ancient than the words for the quantical concepts. In short, the evidence from Pagel and Meade (2018) suggests that number words are generally very old in the three tested families. However, this ancient status holds for a variety of number words tested, and quantical concepts are not represented with particularly ancient labels. Consider, for instance, that one of the oldest and least replaceable words in Austronesian is "ten".

The degree of cross-cultural variability in the word types for 1, 2, and 3 is actually quite pronounced, without pointing to particularly consistent or ancient processes of lexicalization. Twoness and especially threeness are sometimes not lexicalized in hunter-gatherer groups whose subsistence strategies are a better cultural proxy for the human bands that existed prior to the African exodus, but presumably long after the evolution of quantical thought. Some hunter-gatherers, including the Pirahã and Yanomami, have no precise number terms at all (Frank et al., 2008). It is somewhat surprising that "two" and "three" are missing in some of the world's languages if "giving them a name was probably no more difficult than naming any other sensory attribute". (Dehaene, 2011, p. 80) Languages with highly limited number systems are scattered in diverse regions (Epps, Bowern, Hansen, Hill, & Zentz, 2012). Given the limitations of native quantical reasoning, it is perhaps unsurprising that some languages lack robust number systems. What is more surprising, however, is that there are a fair number of populations of healthy adults that lack a precise term for 3, and also others that lack a precise term for 2. And that some people even lack an exact term for 1 (see survey in Hammarström, 2010). Such facts do not demonstrate that our brains do not bias us towards recognizing threeness, or twoness, but do hint that the biases may not be as strong as is presumed under an account whereby threeness and twoness are like other sensory attributes. The easily lexifiable nature of "oneness", "twoness", and "threeness" is seemingly evident in some populations, but evidence is lacking to actually demonstrate the special status, and especially ancient status, of small numbers across language families and regions. Small numbers are apparently labelled in accordance with their utility in particular cultural melieux, as demonstrated further below. The "ease" with which all humans can supposedly label oneness, twoness, and threeness is not clearly evident.

Cultural variability associated with quantity-naming is less remarkable for larger quantities, as there are no serious claims that larger numbers like "thirteen" are simply the result of ancient labelling concepts presented by our native neurobiology. So the extant variation in larger numbers, often associated with cultural factors like subsistence and trade, is not so surprising (see Epps et al., 2012; Everett, 2017). Nor is the fact that many large number words in small non-industrialized populations are infrequently used and are essentially phrasal rather than lexical. Consider the word for "six" in Karitiâna, an Amazonian language spoken by about 300 people who traditionally relied on hunting and limited agriculture and trade, and for whom larger number terms apparently had limited "utility of meaning" (Enfield, 2015):

(1)	myhint	yj-py	ota	oot	
	one	our-hand	another	take	
	"Six"				(Everett, 2017, p. 65)

Such a phrasal and semantically transparent number word is common in many languages in which number words are used infrequently. In contrast, in large industrialized societies, the discourse-based frequency of number words helps yield shorter forms. (For a discussion on the role of frequency in shortening words, see, e.g., Bybee 2007.) In contrast, phrasal numbers like those in (1) are consistent with more recent innovation and/or less frequent usage.

Despite such observations regarding larger numbers, one could reasonably expect that quantical cognition might yield non-phrasal small numbers across all populations, regardless of cultural factors. After all, if these words have an especially ancient status, as Dehaene suggests, they would more likely be reduced phonetically due to frequency of occurrence over the millennia since their innovation. But that does not seem to be the case, since some languages have phrasal numbers for precise quantical concepts—phrasal numbers that are suggestive of possibly recent innovation. (Bearing in mind Pagel and Meade's (2018) findings for Austronesian, Bantu, and Indo-European, discussed above.) In other words, even in languages that refer lexically to quantical concepts like 1, 2 and 3, the relevant lexemes are not always ancient. Instead, as with larger numbers like "six", words associated with quantical concepts may vary in predictable ways in accordance with socio-cultural factors, and are sometimes phrasal. Consider the word for "three" in Jarawara, an Amazonian language unrelated to Karitiâna that is spoken by a small group of people who traditionally relied on hunting and gathering, with limited agriculture and almost no trade:

(2)	fama	ohari-make	
	two	one-with	
	"Three"		Everett (2012, p. 578)

Rather than reflecting the straightforward and ancient labelling of a native quantical concept, this term is constructed with a binary base, like many larger number terms in Jarawara. And like larger number words in many languages, it is constructed in an almost phrasal manner, likely reflecting its infrequent usage or its relatively new status, or some combination thereof (This infrequent usage apparently contributed to the misperception that Jarawara has no number words—see Everett (2012).) If deriving small lexical numbers were simply a matter of labelling universal quantical concepts, we might expect extensive cross-linguistic variability in the word forms used to label those concepts. Yet we would not expect that small number words would be phrasal, would not be phonetically reduced, and would appear to be recent innovations in some languages.

Intriguingly, where we find high degrees of predictability in lexical number systems is less in the expression of quantical concepts, and instead in the structures of larger numbers. In the languages in the world that have numbers beyond five and ten, the evidence of ancient forces shaping number words is more clearly evident in higher numbers as opposed to lower numbers. For instance, in one recent survey of 196 languages representing a very diverse number of language families and geographic regions, it was found that over 85% used decimal-bases, vigesimal bases, or some hybrid decimal/vigesimal system (Comrie, 2013). Furthermore, many of the remaining languages use quinary systems or some other body-based system. Even apparently exceptional bases like the duodecimal and sexigesimal ones, including the ancient Mesopotamian system from which we have inherited our unusual system of telling time, are also body-based. (By most accounts, their aetiology relates to the 12 main knuckle lines of one hand, and the 5 fingers on the other that can be used to count them in a 5×12 manner.) (Ifrah, 2000) There are exceedingly few number systems, for instance the senary system used in New Guinea, that have non-digital bases for higher numbers. Nearly all of the world's number systems are structured around our digits, and our bodies more broadly, in one way or another (see Everett, 2017, pp. 60–82 for further discussion of these points.). Even Jarawara, with its phrasal lower numbers, has quinary-based larger numbers such as the following:

(3)	Yehe kahari With our one hand "Five"	(Everett, 2012, p. 578)
(4)	Yehe kafama With our two hands "Ten"	(Everett, 2012, p. 578)

As with nearly all languages with larger numbers, then, the human hands are critical to higher numbers in Jarawara. This clear structuring is nearly ubiquitous and the largest language families in the world today all have members with decimal bases. This includes Indo-European, Sino-Tibetan, Austronesian, and Niger-Congo, and the ancestral languages of each of these families clearly had decimal number systems. These language families alone represent roughly half of the world's languages in existence today, and a majority of the world's people. Quinary, decimal, and vigesimal bases have existed for many millennia in very many families, and developed independently in many regions of the globe (Everett, 2017, p. 80). In terms of linguistic traceability, the manual origins of higher numbers are quite ancient worldwide, extending to the actual limits of the historical reconstruction of languages. In contrast, the cross-linguistic data do not support the uniquely ancient status of one, two, and three. Note that the suggestion here is certainly not that some languages have/had decimal bases but lack(ed) words for 1, 2, and/or 3. The claim is simply that the cross-linguistic data point to the ancient status of number systems with digital origins, but do not offer clear support for a uniquely ancient status of words for "oneness", "twoness", and "threeness".

From the perspective of Dehaene, a key question, as it relates to cross-linguistic data, is "How did human languages ever move beyond the limit of 3?" (Dehaene, 2011, p. 80) This is certainly a valid question, but another key question suggested by the world's numbers is the following: "Why do human languages vary so much when it comes to native quantical concepts?" Shouldn't we expect more languages to have special, and especially ancient, terms for 1, 2, and 3? It turns out that the evidence for the predictable lexical privileging of 1, 2, and 3 is meagre. In contrast, if a language uses higher numbers, and most do, one can predict with extreme reliability that it uses digitally based numbers. For lower numbers, strong predictions are actually hard to come by. To be clear, I am not suggesting that every single language should have words for 1, 2, and 3, simply because these concepts are arrived at natively. Yet the cross-linguistic data do make one wonder why there is no clearer evidence of lexical privileging of these three quantities, in the ways suggested by Dehaene.

Another way to investigate the putatively privileged status of words for "oneness", "twoness", and "threeness" is to examine the form that they take across the world's languages. In particular, we can investigate whether cases such as Jarawara are atypical. Or perhaps many languages in the world have small number words that are long and phrasal. In contrast, other languages may have short number words due at least in part to their greater frequency of use over time. To further investigate the form of small numbers in the world's languages, and the potential ways in which they are shaped by external factors rather than by the straightforward labelling of "oneness", "twoness", and "threeness", an analysis of number terms in the Automated Similarity Judgement Program (ASJP) was conducted (Wichmann, Holman, & Brown, 2018). The ASJP is a database containing phonetically transcribed words in over 7000 language varieties. Forty basic words from each language variety are represented. (The words are listed here: https://en.wikipedia.org/wiki/Automated_Similarity_Judgment_Program) Critically, these words include "one" and "two" in most varieties. This study focused on 5942 varieties whose lists contain both "one" and "two". Lists for some language varieties, mainly those for reconstructed and constructed languages, were excluded. The length of "one" and "two" was obtained for these 5942 varieties representing 312 language families. The varieties were categorized into families according to the carefully constructed taxonomy in Bickel and Nichols (2017). The length of all 40 words in each of these varieties was calculated by counting the number of phonetic segments in each word. (See *Methods* section for greater detail.) The general question being explored was whether or not the word-length data suggest that cultural factors systematically impact the use and structure of number words associated with quantical concepts. The measure of usage is indirect: word length in terms of phonetic segments. The choice of this measure seems sufficiently well grounded since shorter word lengths generally correspond to higher frequency in discourse (Bybee 2007). In contrast, longer words are generally suggestive of lower frequency in discourse and/or a newer status in the history of a language. So, to be clear, if Dehaene's suggestion about the especially ancient status of "one", "two", and "three" is accurate, we could expect some evidence for this in the form that the world's small numbers take. That evidence might include shortness of number words across populations, regardless of cultural factors. More broadly, though, an exploration of number-word length is useful to understanding how the world's cultures derive number words, and whether or not there is any hint that 1, 2, and 3 are like "sensory attributes" in terms of their namability.

The first point to be addressed in this exploration is whether frequent words really are more phonetically reduced in the ASJP data, and the evidence suggests clearly that they are. (See *Methods*.) While relevant cultural data (like the extent of reliance on external trade, addressed below) are not available for most languages, the ASJP database does contain population data for each language variety. These population data are used here as an imperfect proxy for non-linguistic cultural factors like trade, since hunter-gatherers tend to live in small, isolated populations and since larger populations generally rely more heavily on trade and other practices that require exact numbers. Figure 1 contains several scatterplot heatmaps depicting the association between the length of "one" and "two", respectively, and population size. (Heatmaps are used to avoid overplotting.) As seen in panel A, for "one" there is an apparent decline in word length in accordance with population size, bearing in mind that population size is not being claimed as the direct causal factor here. In panel B it is evident that the decline also holds for "two". The data in Figure 1(A,B) reveal greater variability in the length of "one" and "two" for smaller populations. In contrast, larger populations exhibit less variability as evidenced by the darker upper-right quadrant in the two panels.

Recent work suggests that larger populations may have less robust morphologies. According to the "linguistic niche hypothesis", large populations disfavour complex morphology since it inhibits language acquisition by adult second language learners (Lupyan & Dale, 2010). One account of the patterns in panels A and B of Figure 1 is that the ASJP data, while supposedly containing lemma forms of basic words, may include extraneous bound morphemes in the case of some smaller populations. In other words, perhaps the ASJP words are just generally shorter in larger populations. This possibility is difficult to reconcile with panels C and D in Figure 1, however. These panels depict the length of "one" and "two", respectively, when contrasted to the average word length in the same language variety, based exclusively on the 40 ASJP words. (The average length was subtracted

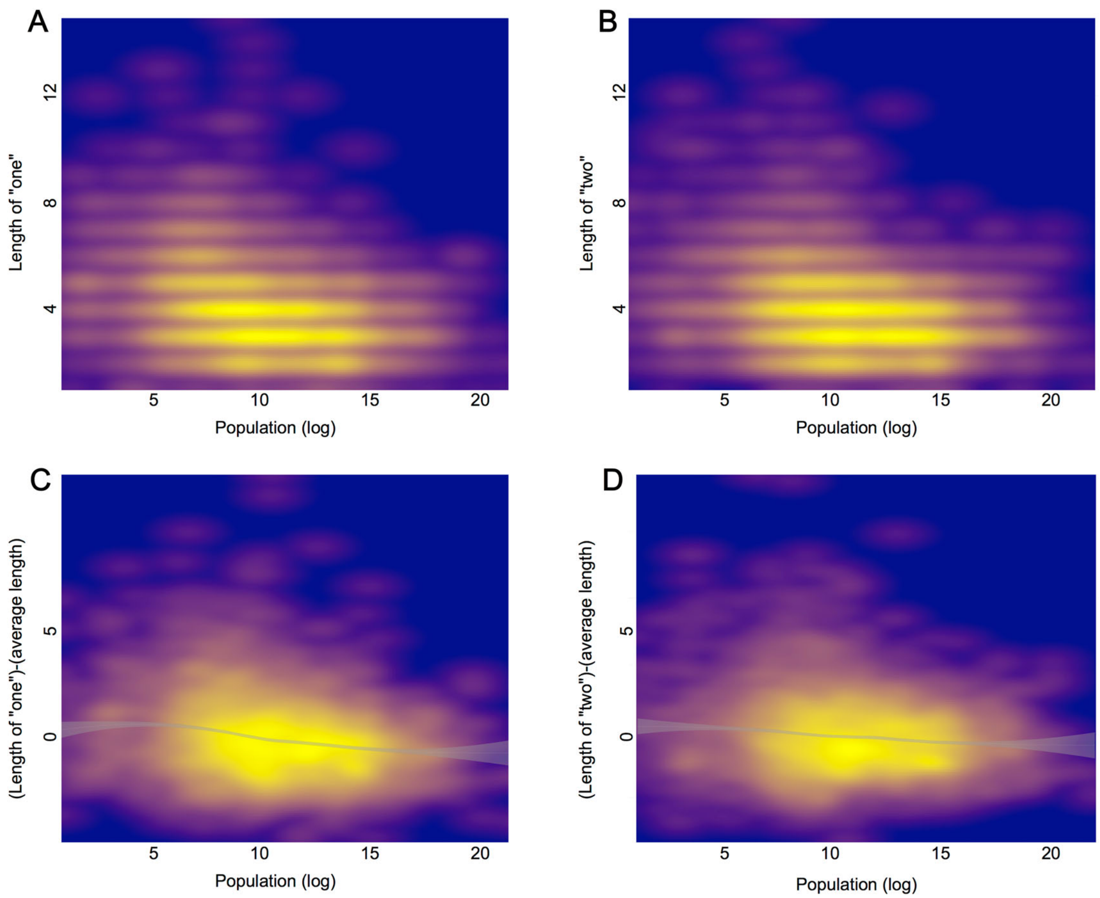

Figure 1. The length of words associated with precise quantical concepts, based on the ASJP database. Dark blue regions correspond to regions with zero plot density, and yellow intensity corresponds to higher plot density. (A) The length of "one" across 5942 language varieties, by population. (B) The length of "two" across the language varieties, by population. (C) The length of "one" when compared to the average word length, for each language variety. Average word length was subtracted from the length of "one", for each word list. Contour represents a locally weighted regression, with surrounding confidence gap. (D) The length of "two" when compared to the average word length, for each language variety. [To view this figure in colour, please see the online version of this journal].

from the number-word length to arrive at the figures.) The data in the panels suggest that, in languages with many speakers, "one" and "two" are typically shorter than the average word. In contrast, across small populations these number words are on average the same length as other words, though across small populations there is extreme variability in terms of the length of "one" and "two". In other words, their length is unpredictable in small populations, and relatively predictable and typically short in larger ones. This does not hint that words for one and two are particularly ancient across populations. If they are, in some cultures they are apparently used so infrequently that they have not been phonetically reduced over millennia. One plausible interpretation, it would seem, is that these words have only recently been innovated, due to language contact or other external phenomena, in many of the world's smallest populations. This interpretation offers a parsimonious explanation of the data in Figures 1 and 2. In and of itself, this may be construed as a somewhat banal fact. Yet it is an observation that is missing in the literature and is worth drawing attention to, particularly since it further calls into question the putatively privileged status of small numbers. In short, the form of the world's small number words does not hint at any uniformly special or especially ancient status.

Languages in the bottom quartile, population-wise, tend to have much more scatter in the word length for "one" and "two", when contrasted to those in the top quartile. The standard deviation of the word length of "one", in terms of number of phonetic segments, is about 50% greater in the bottom quartile than that in the top. (1.57 vs. 1.05 phonetic segments) The standard deviation of the length of "two" is about 63% greater in the bottom quartile than in the top. (1.6

vs. 0.98 phonetic segments) Such differences surface even after controlling for language relatedness via random sampling that represents each language family equitably. (See the *Methods* section for details on the random sampling approach.) These patterns could be influenced by contact-based effects but, if so, this influence would simply offer greater support for the notion that cultural factors like trade impact the form of small number words. If "one" and "two" are influenced inordinately by language contact, this runs counter to the notion that these words are simply natural labels for "oneness", "twoness", and "threeness".

Since population is not being claimed as the direct causal factor here, what might the causal factor be? More than likely a host of factors are involved, only some of which may be associated with population size. One potential causal factor is the degree to which languages are used in trade. After all, unlike isolated hunter-gatherer populations, trade-heavy groups tend to rely on precise number terms when selling, buying, and bartering. So we might predict, then, that trade-heavy groups have more frequent and shorter number words, on average. This certainly seems a straightforward prediction for larger numbers, but the issue at hand is whether such a prediction holds even for number words associated with 1, 2, and 3. One approach to exploring this possibility is to cross-reference the 5942 word lists being used with a database containing information on trade. One such database is Kirby et al. (2018), which classifies some cultures according to the degree that they rely on trade. Cross-referencing the 5942 language varieties with Kirby et al. (2018) yields only 134 cultures with word-length data and reliable information on the degree of trade associated with the relevant linguistic communities. These populations are geographically and linguistically diverse, representing 79 distinct language families. (This is not a coincidence as the database was designed to represent diverse regions and language families.) This cross-referencing yielded the results summarized by the beanplots in Figure 2.

The vast majority of the 134 cultures are grouped into one of three trade-level categories, namely categories 2, 4, and 5. Only one culture is sorted into the most intense trade category, making that category uninformative. Particularly if we focus on the three major categories, we see that the mean length of these small number words does decrease in accordance with trade (even compared to other words in the same language). Given the range of families and regions represented, these findings offer greater support for the claim that "one" and "two" are shaped by cultural factors, rather than supporting claims that such quantities are labelled in straightforward and ancient ways like sensory attributes typically are. Admittedly, more data are required to explore this issue and no strong claims of causality are being made here about the roles of cultural factors in shaping small numbers. (See Epps et al., 2012 for a discussion of the impact of cultural factors on number limits.) What this word-length exploration has shown, like the rest of this study, is that quantical concepts are not linguistically privileged in readily identifiable ways. There is no clear evidence, for instance, that they were lexicalized anciently when compared to other numbers. On the contrary, these data are more easily reconcilable with the possibility that these words are comparatively recent innovations in small hunter-gatherer cultures, or at least used without high degrees of frequency. Consider English as a counter-example to these small cultures: English words for small numbers are generally phonetically reduced: "one" /wən/, /tuʊ/, and "three" /θɹi/ are all monosyllabic and 2–3 segments (consonants and vowels) in length. In contrast, numbers beyond ten are generally polysyllabic and have quasi-opaque phrasal origins: "thirteen" /θɝtin/, "fourteen" /foɹtin/, "twenty-one" /twənti wən/, and so on. The data presented in this section suggest small number words in many languages are phonetically more similar to higher numbers in English than lower ones.

4. Discussion and conclusion

This work suggests native quantical concepts are not grammatically and lexically privileged, at least not in some of the ways suggested in the literature. This does not imply, of course, that 1–3 are not natively distinguishable. There is extensive evidence that they are. But, especially in the light of that evidence, some interesting questions arise once we carefully consider grammatical and lexical numbers from a cross-linguistic perspective. These include: Why do languages sometimes have no terms for small numbers? Why is the truly verifiable limit of precise grammatical number not 3? Why are words for 3, 2, and even 1, shaped by usage-based factors, offering little evidence

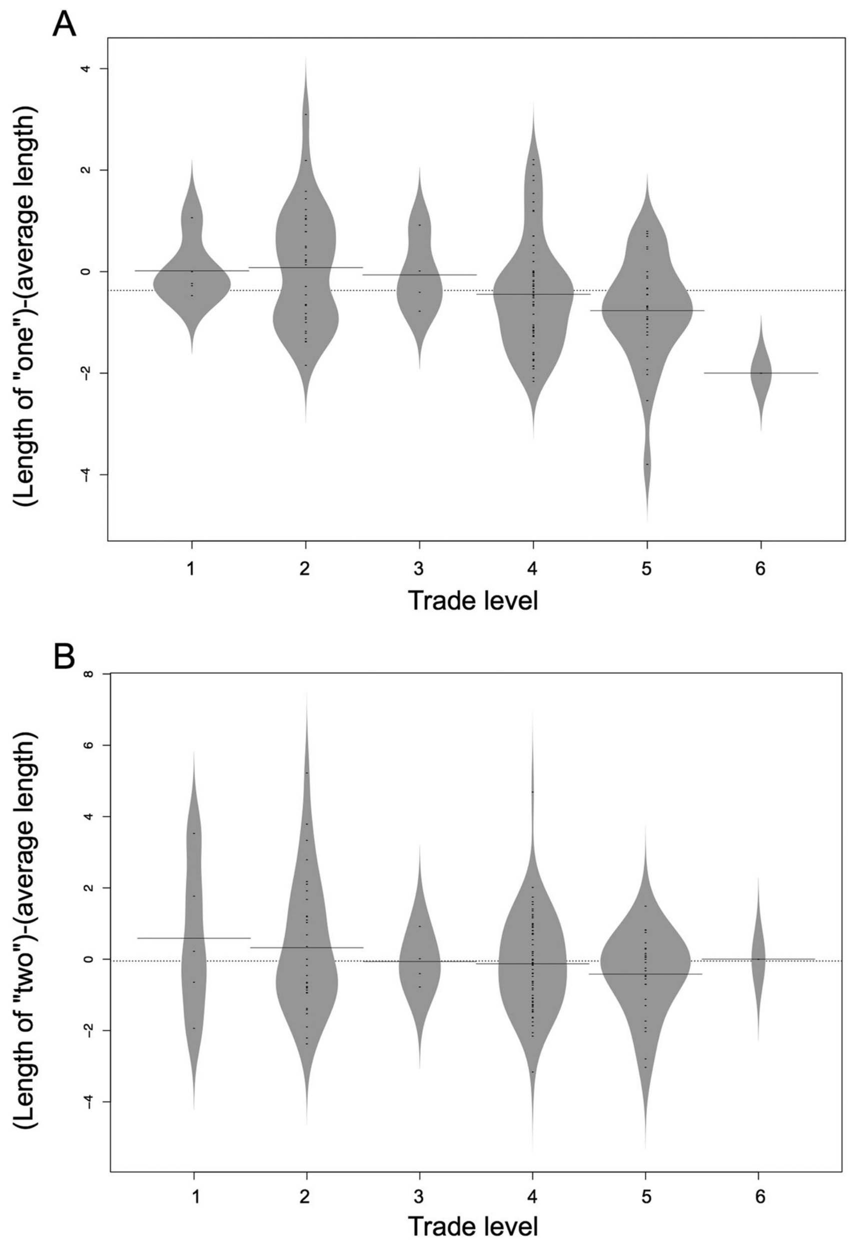

Figure 2. (A) Beanplots depicting the length of "one" (when contrasted to average word length), in accordance with the degree of trade in 134 distinct cultures. (1 = No extra-community trade, 6 = Intense extra-community trade.) Bean widths represent the density of the individual values along the *y*-axis. Dots along the centre of the beans represent individual languages/cultures. Horizontal lines through beans indicate the mean length of "one" for each trade level. (B) Beanplots depicting the length of "two" (when contrasted to average word length), in accordance with degree of trade.

that they function like ancient labels of native sensory attributes? In short, why don't small numbers have a discernible special status of some kind? A careful elucidation of the cross-linguistic data yields new questions about the relationship between native quantical thought and numerical language.

In what ways are quantical concepts actually privileged in the world's languages? Words for 1 exist in nearly all languages, and grammatical categories for singular and plural are extremely common and functionally flexible. Beyond that, there is a clear decline between 1 and 2, in terms of how privileged the concepts are lexically and grammatically, and an even steeper decline between 2 and other quantities. It is important to acknowledge the messiness of the cross-linguistic data as they relate to the way in which humans refer to native quantical concepts. Consider that languages could, in theory, consistently use singular, dual, and trial markers. All languages, or nearly all languages, could have ancient words for oneness, twoness, and threeness—words that did and do not require significant cultural utility in order to take shape.

Native neurobiology no doubt plays a key role in scaffolding grammatical number and lexical numbers. But the cross-linguistic data suggest that there is no neat relationship between some blueprint of our cerebral architecture and the edifice of numerical language constructed in a given culture. Critically, this is true even with respect to the grammatical and lexical means languages use to refer to 1, 2, and 3.

5. Methods

The word-length data are available upon request, as is the code used to derive those data from the ASJP. The analysis presented above is also based on previous surveys of number words and grammatical number, primarily Comrie (2013), Dryer (2013), and Corbett (2000).

For the word-length analysis: The lengths of the 40 basic words in the ASJP database were ascertained via a function created with the *stringr* package in R. This function was applied across all word lists, but this analysis focused on those 5942 lists with transcriptions for both "one" and "two". Word length was calculated by summing all of the phonetic segments (consonants and vowels) in a given word. Factors such as nasality were not included, only segments that necessarily yields longer words. When more than one variant of a word was given in a list, the variants' lengths were averaged. The ASJP encodes characters of the International Phonetic Alphabet with special computationally friendly symbols. These symbols were consulted in order to accurately calculate word length in terms of phonetic segments. (See Wichmman et al., 2016).

All 40 ASJP words were ranked by their frequency in English discourse, and then this ranking was contrasted with a separate ranking of the words by their average length (based on all 5942 lists). This contrast of rankings suggests a global association between word length and word frequency. (Spearman's rho = 0.36, $p = 0.02$) The average length across all 40 words, for all word lists, is 4.1 phonetic segments. The association between frequency and length is driven in part by the two shortest words: "I" (mean length = 2.95 phonetic segments) and "you" (mean length = 3.02 phonetic segments). These pronouns are also the most common words in English. Furthermore, pronouns are well known to be common in other languages. In contrast, the longest two words in the database are "star" (5.46 phonetic segments) and "knee" (5.31 phonetic segments), which are reasonably assumed to be much less frequent than pronouns in all or nearly all languages.

Figure 1 was generated via the *scatterPlot* function in R. Subsistence strategies for the languages depicted in Figure 2 were found by cross-referencing the word lists with the Murdock and Morrow (1970) database available online via D-PLACE (Kirby et al., 2018). This yielded only 134 languages with clear subsistence data, which were plotted in Figure 2 via the *beanplot* package in R.

To further test for the greater length variability in smaller populations, evident in Figure 1, the 5942 language varieties were categorized into quartiles according to population. The population data are provided in the ASJP database. The top quartile and the bottom quartile were examined to see whether the lengths of "one" and "two" were more variable in the bottom quartile, when contrasted to the top quartile. To do so, the difference between a) the length of "one" in a given language and b) the average word length in that same language, was ascertained for each language variety. The same was done for "two". The standard deviation of these differences was calculated for all the languages in the bottom population quartile and for all of those in the top quartile, respectively. For "one", this "standard deviation of differences" was 1.05 for the top quartile and 1.57 for the bottom quartile. For "two", this "standard deviation of differences" was 0.98 for the top quartile, and 1.6 for the bottom quartile. These quartile contrasts suggest that the length of number terms for 1 and 2 is clearly more variable in small populations. But such simple contrasts do not control for phylogeny. Word lists were cross-referenced with the AUTOTYP database (Bickel & Nichols, 2013) via ISO codes in order to control for relatedness by sampling from the AUTOTYP language families. A random sampling approach was then used to contrast the quartiles, via a function written in R: For the bottom quartile, one-word list from each language family was randomly selected. For this new sample equitably representing each family, the standard deviation of differences for "one" was obtained, based on all of the languages in the sample. The same was done for a sample representing one randomly selected language variety from each family in the top population quartile. The standard deviation of differences for "one" in the top quartile's sample was then contrasted with the standard deviation of differences for "one" in the bottom quartile's sample. One thousand iterations of this sampling technique were run. For all one thousand iterations, the standard deviation of differences of the bottom quartile was greater than that of the top quartile. The exact same approach was used for "two", and once again in all one thousand iterations the standard deviation of differences of the bottom population quartile was greater than that of the top quartile. In short, the greater scattering of the length of small number words in smaller populations, evident in Figure 1, is not due to phylogenetic biasing.

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Disclosure statement

No potential conflict of interest was reported by the author.

Data availability statement

The data that support the findings of this study are available from the corresponding author, CE, upon reasonable request.

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