Cognitive and communicative pressures in the emergence of grammatical structure: A closer look at whether number sense is encoded in privileged ways

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DOI: https://doi.org/10.1080/02643294.2020.1802241

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Acknowledgments
This study is supported by H2020-MSCA-IF-2017 SNANeB, Project No: 795242 to RR and by European Research Council Grant 679010 (ERC STATLEARN to Davide Crepaldi) to FF.

Keywords: core cognition, non-verbal numerical systems grammar, number morphology, language universals, communicative efficiency.

In a recent article, Everett (2019) proposed a culture-centered account of the distribution of the observed values for an almost universal grammatical feature, morphological Number (Haspelmath 2013). In developing his argument, Everett criticizes prior analyses, which highlighted the role of non-verbal numerical cognition in constraining the regularities observed cross-linguistically for grammatical Number (Franzon, Zanini & Rugani 2019). We find Everett's (2019) perspective to be very insightful. However, we think that his critique of Franzon and colleagues (2019) is based on an inaccurate interpretation of that proposal. This minimizes the importance of our analyses, and our arguments for a complex interplay between the non-verbal numerical systems and Number morphology, modulated by cognitive and communicative factors. Here we clarify our hypothesis, explaining why an account based only on cultural grounds neither sufficiently nor economically explains what is observed for one of the most widespread features across natural languages.

Basic morphological Number systems include, at least, the opposition singular *vs.* plural ('car' *vs.* 'cars'). This is the necessary condition for other values to surface: dual, trial, (debatably quadral), and paucal, respectively meaning two, three, (four), a few (Corbett 2000; Greenberg 1963; Malouf, Ackerman & Seyfarth 2015). Moreover, no morphological Number value has ever been observed to denote an exact numerosity out of this range, equal to e.g. five, twenty-one, one million.

In our typological survey, we highlighted the parallelism between the Number values observed in morphology and the numerosities handled by the non-verbal numerical systems (Franzon et al. 2019). These cognitive systems, the Object File System and the Analogue Magnitude System, respectively allow the identification of three/four units, and the estimation of larger numerosities (Rugani 2018). Their phylogenetic ancestry and early availability across the animal kingdom support their biological relevance for providing salient evaluation of environmental factors (e.g. estimating the number of companions or predators; Cantlon & Brannon 2007; Rugani et al. 2015). Non-verbal numerical cognition is pivotal for biologically successful behaviors, and is one of the

Core Knowledge Systems (Spelke 2000). The basic constraints of Core Knowledge have been proposed to influence human numerical cognition, even in the symbolic mode (Cantlon, 2018). The advantage of an efficient mechanism for communicating numerical information to conspecifics easily follows. In this regard, morphology encodes, consistently across languages, only certain semantic features besides numerosity. All of them seem closely related to the information processed by the Core Knowledge Systems, such as animacy, time, and space, respectively surfacing in grammatical Gender, verbal Tense, deixis. Backed up by these observations, we had suggested that morphological Number encodes the information driven by the non-verbal numerical systems, and that the saliency of such information shaped languages' grammars to optimize its encoding.

This research perspective has been partially reviewed in Everett (2019). The author claimed that core cognitive biases in recognizing numerosity would not manifest as robust patterns in the cross-linguistic distribution of morphological Number values. Given the scarcity of attestations of trial and quadral, and their geographic diffusion, Everett concludes that core knowledge would not play any role in the observed typological distribution, which would be exhaustively explained by cultural and areal factors.

Cultural factors cannot be disregarded; indeed, we note here that more than one factor contributes to both the similarities and differences observed in the distributions of morphological Number values. Non-verbal cognition is one such factor, which likely constrains the observable *limits* in language variation. Within these limits, the distribution and frequency of occurrence of the Number values is modulated by usage and referential factors. However, the limits of the possible values observed in morphology are *per se* not sufficiently explained only «by usage-based factors» (Everett 2019: 3).

As a non-linguistic example, we can consider how not in all human cultures chairs are used to assume a seated position. When chairs are devised for this purpose, they can vary in shape and size; however, the size of chairs does not exceed the size that would be possible to use for humans. Whereas the frequency or typicality in the size of some

chairs depend on their use, the limits of the size of this cultural invention are built on a biological constraint, namely the size of its human users. We suggested a similar hypothesis to account for the parallelism between the numerical cognition and the morphological Number values: the observed limits of these latter resemble the ones set by the Object File System and Analogue Magnitude System, while the distribution of values occurring within these limits and their frequency of use are very likely modulated by usage and communicative pressures (Franzon et al. 2019: 44, 46). As stated in Bickerton (2007), biological evolution and cultural diversity are two well-distinct (although often confused) fields and «within the envelope of the language faculty, languages are recycling the limited alternatives that this biological envelope makes available» (Bickerton 2007: 511). The cognitive ability sets the limit; distributions inside that limit are modulated by diverse communicative factors, including cultural relevance. In this respect, morphological trials can exist, although rarely attested, whereas morphological Number values referring to exactly six units, such as the “sextal” coined by Everett (2019), cannot possibly be ever attested in natural languages, as they would lay outside the processing capabilities of non-verbal numerical systems. Undoubtedly, lexical items (like nouns, or adjectives) denoting a reference to a numerosity of six can be introduced in the lexicon of any language. The lexicon is an open class, expandable by adding new words concerning potentially any semantic domain. Such words are indeed commonly present in languages. A word meaning ‘six’ can also occur more frequently than nouns inflected in the dual or trial; however, the frequent denotation of the concept of ‘six’ cannot give rise to a morphological “sextal”.

Nonetheless, recent evidence shows that the use of number words in spontaneous language depends on numerical ratio - a clear signature of Weber’s law and of the Analogue Magnitude System (Rinaldi & Marelli 2019). Differently from the lexicon, grammatical morphemes are closed sets of elements, and are much more constrained with respect to the semantic features they can encode (Strickland 2017). In this light, it is not unreasonable to trace a parallelism between the processing of the number three by the non-verbal numerical systems and the potential admission of trial in the morphological Number systems. In our opinion, neither the rarity of trial across languages nor the fact that its emergence is constrained to «one semantic domain»

(Everett 2019:6) disprove this parallelism. First, because the involved semantic domain is animacy, whose influence in processing numerosity has been noted, both at the cognitive (Rugani et al. 2010) and linguistic levels (Corbett 2000; Zanini et al. 2020). In addition, the trial mostly surfaces in salient contexts, as reported throughout the literature (Corbett 2000).

Most importantly, the fact that morphological Number systems do not encode one-to-one into dedicated values all of the distinct information processed by the Object File System and the Analogue Magnitude System, does not imply that languages «inefficiently encode a core cognitive feature» (Everett, 2019: 5). Conversely, this could be a sign of communicative optimization. Most languages grammaticalize a singular *vs.* plural opposition, compressing the encoded information with respect to the referential one processable by non-verbal numerical cognition. We relate this fact to an intrinsic property of codes in general, and of languages in particular. Akin to the way lexical hypernyms (*dog*) underdetermine hyponyms (*beagle*), in Number morphology the plural can underdetermine a reference to two, three, few and more than few. Likewise, the loss of information also affects the value of singular, which can denote a reference irrespective of its numerosity or countability (Franzon et al. 2019: 41, 44; Everett 2019: 3).

Communicative efficiency requires a trade-off between costs and benefits of encoding (Ferrer-i-Cancho et al. 2019). Since numerical information is salient, communicating it will bring some benefits. However, the cognitive costs of encoding all the numerical information all the times would possibly overcome the benefits. This balance also needs to evaluate that, besides encoding semantic information, morphology also plays a functional role in building sentences. Morphological features allow the establishment of syntactic agreement between phrasal elements, and facilitate comprehension by reducing ambiguity between related words during sentence parsing (Dye et al. 2017; Wicha et al. 2004). This works out even with a small set of morphological features, which can be as low as two (Franzon & Zanini 2020; Ramscar 2019).

Therefore, more factors, including numerical cognition, general properties of codes, and communicative pressures, synergistically work to encode referentially salient

information, while keeping affordable the amount of cognitive costs related to sentence processing. As a result, morphological Number systems are never maximally informative, and the referential information is in every case compressed into a simpler, less discriminative, system.

This does not exclude the possibility that non-verbal numerical information can be accessed while processing even the simplest morphological Number system. Faster responses have been found on left side for words inflected in the singular and on right side for words inflected in the plural suggesting a SNARC-like effect in response to morphological Number (Roettger & Domahs 2015). Moreover, electrophysiological activity elicited after a mismatch between a visually presented numerosity and morphological Number on a referring word resembles a response to a grammatical violation (LAN-like effect; Arcara et al. 2019). Neuroimaging evidence suggests that neural areas associated with non-verbal numerical processing are activated following the presentation of a Number agreement violation (Carreiras et al. 2010).

These preliminary results merit additional research. In this regard, we agree with Everett (2019) on the necessity of further empirical evidence focusing on typologically diverse languages. Furthermore, experimental data on Number processing will shed some light on morphological encoding and its relation with numerical cognition.

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