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TOWARDS AN AGENDA TO INVESTIGATE LANGUAGE DEVELOPMENT IN AN INDIGENOUS GROUP IN THE AMAZON

PARA UMA AGENDA DE INVESTIGAÇÃO DO DESENVOLVIMENTO DA LINGUAGEM EM UM GRUPO INDÍGENA NA AMAZÔNIA

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ABSTRACT

The present work advances a research agenda within the broader field of language and cognition for the study of the expression of numerical concepts in early development. Lying at the core of the proposed agenda is the question of the relationship between the acquisition of the first language and the expression of numerical concepts in infancy. Two processes exist to explain the expression of numerical information in languages. The first takes place through the grammatical structure of language (its quantificational system). The second is the direct expression of number with the use of number language expressions. The first process is called "grammatical number", the second, "linguistic number". In an attempt to raise questions that lie beyond previous investigations, and to expand linguistic and cognitive considerations, the proposal includes discussions regarding various numerical abilities in differing linguistic contexts in light of conceptual development of number systems. We hope this proposal will raise interesting cognitive and linguistic issues within the scope of languages spoken by native Amazonian peoples.

KEYWORDS: Quantification and numeracy skills. Number systems and conceptual development. Language acquisition. Language and cognition. Amazonian languages.

RESUMO

O presente trabalho avança uma agenda de pesquisa no campo mais amplo de linguagem e cognição, com vista ao estudo da expressão de conceitos numéricos no desenvolvimento inicial. No cerne da agenda proposta, está a questão da relação entre a aquisição de primeira língua e a expressão de conceitos numéricos na infância. Existem dois processos para explicar a expressão da informação numérica nas línguas. A primeira se dá por meio da estrutura gramatical da língua (seu sistema quantificacional). A segunda é a expressão direta do número com o uso de expressões de linguagem numérica. O primeiro processo é denominado "número gramatical", o segundo, "número linguístico". Na tentativa de levantar questões que vão além das investigações anteriores e expandir as considerações linguísticas e cognitivas, a proposta inclui discussões sobre várias habilidades numéricas em diferentes contextos linguísticos à luz do desenvolvimento conceitual de sistemas de numeração. Esperamos que esta proposta levante questões cognitivas e linguísticas interessantes no âmbito das línguas faladas por povos originários amazônicos.

PALAVRAS-CHAVE: Quantificação e habilidades numéricas. Sistemas numéricos e desenvolvimento conceitual. Aquisição da Linguagem. Cognição e linguagem. Línguas amazônicas.

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Introduction

For the past several decades, researchers in the cognitive sciences have been fascinated by how children acquire language. We thank scientists such as Noam Chomsky, John Macnamara, Susan Carey, Lila Gleitman or Thomas Bever, to name just a few, for raising such fundamental questions. However, when proposing to investigate language acquisition in early development, researchers are required to make a choice – acquisition of what? Word learning? Agreement? Syntax? Pragmatics and context?

One area in the study of language acquisition that has proven fruitful – not only due to its intrinsic interest, but also due to the kinds of questions that the investigation leads to – is the area of mathematics. Research with infants show rudiments of numerical knowledge within the first year of life, for example (ULLER, 1999, 2008, 2009; cf. also ULLER, 2019 for a discussion of the relationship between number and language). In the education realm, mathematical abilities have been suggested to predict educational and financial success later in life (see, for ex. RICHIE & BATES, 2013), and efforts to predict relationships between preschool numerical mastery and academic success have been attempted (e.g., BRAHAM & LIBERTUS, 2016).

Theoretically, the interest in language acquisition[3] and numerical knowledge transcends the question of whether mastery of numerical concepts leads to academic success in life or not. This relationship directly taps into a question that has triggered the curiosity of/has puzzled linguistics and anthropology investigators for over a century - what is the relationship language – thought? Do we think first, express after? Or are we guided by a linguistic system so deep-seated in our human cognitive architecture that we cannot think or we cannot have concepts that are not linguistically bounded?

Of course that here we refer to the debate originally raised by Humboldt, amongst others, in the 1800s, about linguistic determinism, which was formally formulated by Sapir's and Whorf's publications in the 1960s. Since then, the relationship language-thought has puzzled linguists, anthropologists, psychologists, philosophers alike. For Sapir-Whorf, language does not only mirror reality – it shapes how we see and experience the world. This linguistic relativity is directly and intrinsically associated with the cultural attributes of the group that speakers belong to. While Sapir and Whorf differed in the degrees of determinism (for ex., Whorf seems more committed than Sapir to the postulation of linguistic determinism in perception, in fact, a philosophical question), in the strong version of the hypothesis, this view has become what we know as the Sapir-Whorf Hypothesis.

A so dubbed "weaker" version of this hypothesis in its degree of determinism – that the language of a group will reflect and influence how the speakers of the group see and think about the world – has been the focus of groups of researchers in different fields of investigation. Take Slobin, for example. Slobin proposes, since the early 1980s (and discusses proposals of the "weaker" version of the hypothesis by Pinker and Levelt), that there are "pervasive effects of language in selective attention

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[3] We use indiscriminately language acquisition and language development; we recognize that the expressions mean slightly different things, but will avoid engaging in the debate here.

and memory" (SLOBIN, 1996). That is, in studies of various languages, especially in translation studies, it has been noted that there may be semantic, contextual and pragmatic circumstances in which a language will influence how speakers think about the world. One such example is reported in Slobin (1996):

> If I tell you about my "friend" in English, you will expect that sooner or later you will discover the sex of the friend, because you know that third-person pronouns in English indicate gender. If I go on to refer only to "my friend" or "they" you will begin to suspect that I have reason to conceal the person's gender. However, if we have the same conversation in a language that has no gendered pronouns, such as Turkish or Chinese or Hungarian, you probably will not have such suspicions. When speaking English, my thinking for speaking is tuned to gender and its communicative significance, and your "listening for thinking" is similarly tuned. We are not concerned with real world cognition here, but rather with the ongoing construction of mental representations. Our basic cognition of gender does not change when we switch languages, as far as I know, although our social and cultural cognition may well change. Communication is embedded in culture, and much of culture is carried—indeed, constructed—by language. Therefore the definition of cognition should not be restricted to phenomena of the physical world alone.

The debate counts on evidence from languages spoken in cultures that express their diverse environments in a variety of different ways. Research on colour perception and expression in languages (originally, HEIDER & OLIVER with Dani speakers, 1972); KAY & KEMPTON with Tarahumara speakers, 1984), ROBERSON, DAVIES and DAVIDOFF with Berinmo speakers, 2000), for example, suggests that speakers in different cultures will use their linguistic knowledge in the recognition and judgments of colours and colour names. One might argue, however, that colour, one of the most cited cases in this debate, may be unique. There is something special, particular, about how we experience the visual world. We now know from psychophysics that the brain processes visual information in rather individualized ways (see, for ex., HURLBERT & LING, 2012). Therefore, it would come as no surprise that there would be significant individual, and cultural, differences in the ways we name different colours.

Another example is the case of evidentiality. Children learn to use context to share information that may have been experienced by themselves, or reported as experienced by someone else. Evidentiality deals with linguistics markings (affix, clitic, particle, etc.) in the structure of certain languages that indicate the speaker's source of information for the content of the message they wish to convey (AIKHENVALD, 2006). In languages such as Bulgarian or Turkish, evidentiality is grammatically marked to indicate whether the content of the speaker's message is knowledge via direct experience, or knowledge coming from another/other source/s (inferential). Children must master this in the process of language acquisition. Some suggestions exist that entertain the possibility that the use of linguistic representations (such as evidentiality) might help the development of non-linguistic information (e.g., source monitoring of knowledge). One of the ways of testing this is to carry out cross-linguistic studies of languages that have/do not have grammaticalised evidentiality. The results in the literature have been ambiguous, thus indicating that the issues around the Sapir-Whorf are as much debatable as ever (see, among others, GOPNIK, 2001; UNAL & PAPAFRAGOU, 2016).

Perhaps here the distinction between *cognitive dominance* and *linguistic dominance* first proposed by Gentner et al. (2001) could prove useful. In this and following publications, Gentner and colleagues suggested that, in information processing, and in conceptual and linguistic structuring, there may be two processes at play. First, there could be parts of the perceptual experience that would (almost automatically) clump together to form "conflations" that are conceptualized and then translated into the lexicon as unified concepts. This is called *cognitive dominance*, that is, concepts arise from the cognitive-perceptual processing and are named in language. Second, in *linguistic dominance*, imagine that the world is composed of perceptual parts whose clumping is not predetermined, and language has a say in how the parts get "conflated" into concepts. We follow Gentner's (1988) proposal of a "division of dominance" in which words are categorized as "open class" or "closed class" words. Open-class words are large lexical categories such as nouns, whereas closed-class words serve grammatical functions. In this framework, nouns for objects, for example, would follow cognitive-perceptual dominance, whereas verbs, prepositions, determiners, which perform relational functions in language, generally appear in high frequency, and are generally unique to each language (which makes translation difficult), would follow linguistic dominance – their meanings are "shaped" by languages.

The best way to assess this distinction, in our view, and most importantly, in order to shed more light into this debate, would be to investigate the process of number word learning in children, speakers of languages which themselves offer opportunities for cognitive and linguistic analyses given their unique structures.

The agenda

Human beings, regardless of the socio-cultural context experienced, speak languages that, one way or another, will express numerical content. We identify two broad, overarching processes for the expression of numerical information in languages – the first occurs via the grammatical structure of a particular language x (language quantification system), we will dub this "grammatical number".

For example, in Portuguese,

Abraçaram-se longamente

is a perfectly grammatical statement which means that two people embraced each other at length. In Portuguese, the sentence does not contain a subject, because the verb "abraçar" denotes two people. The structure also contains an enclitic pronominal form "-se" which in English would require "each other", a so-called reciprocal pronoun.

Implicitly, therefore, be it in Portuguese, English, or we assume, any other language, one presumes that numerical content is expressed in language in various ways of implicit knowledge. Another way of expressing a numerical concept in language implicitly regards the use of articles. For example, in Portuguese, “um/uma” denotes one, “outro/outra” denotes another one, different from the first. There is an implicit assumption of “twoness” expressed naturally in the use of articles in this way. Adjectives and adverbs can also express an implicit numerical understanding. For ex., “many”, “more”, “less”, “a few”, “several”, etc., are natural expressions that bear numerical content. So are expressions such as “both”, “none”, “pair” in English, which directly implicitly contain numerical information.

The second process of numerical content expression is the direct expression of number with the use of linguistic numerical expressions. We will dub this “linguistic number”.

For example, any typically developing 40- to 42-month-old toddler, native speaker of Portuguese will nail the counting routine “um, dois, três, quatro, cinco, seis, sete, oito, nove, dez”. So will the Portuguese as second language learner in lesson no. 1. We assign the count to items to be counted in sets, whether it be cookies, unicorns, dragons or ideas. Or whether the set of items is in front of us, or in memory.

This binary system of analysis, grammatical v linguistic number, can be useful when structuring empirical testing with populations of a sensitive nature, for example, children or participants of an indigenous group, but in particular, when the topic under investigation is of a certain nature. Numerical cognition deals with an abstract concept, insofar as the concept is not perceived in the world as direct experience, such as colour is, for example. Number is an attribute of a set of entities (be it objects, such as apples, entities, such as unicorns, or ideas), we have direct experience with such, but the concept of “how many” exists as a function of the processing of information that is absent from the direct perceptual experience. That is, humans, and animals, as it turns out, represent numerical concepts with or without language. The question is – what is the role of language when representing number? And how can we bring data from speakers of languages which lack lexical items denoting numerical concepts in phase of language acquisition to bear on the question of the relationship between language and number that would add to the debate?

Two systems of number

In the study of how human beings represent numerical concepts, and express number in language, research to date reveals a consensus that there are two cognitive systems underlying how we count [please note that here we will focus on counting and the use of words in language for counting of integers]. Here we briefly review these systems in light of empirical data.

Since the seminal work by Gelman and Gallistel (1992, for a review), we know that children attain the mastery of counting by around age 3-4. This means that children at this age can use lexical items in language to denote with precision the quantities expressed in counting routines – “one” for one item being counted, “two” for two items being counted, “three” for three items being counted, and so forth and so on. This entails that children make use of what Gelman and Gallistel dubbed the principles underlying counting. For example, that we count each item only once; that the naming order in the count is always the same; that we count anything (from objects in front of us to magical creatures such as gremlins, or to ideas we had yesterday), that in a group, we can count items irrespective of whether we start counting them from left to right, or right to left; but most importantly, that the last item in the naming count determines the cardinality of the set – when the child states one, two, three, three will denote the numerical value to be represented.

There is plenty of evidence that this process exists in humans by the age of four years. Le Corre (this volume) points out sensitively that this mastery of verbal counting by children at this age has been shown in a variety of different measures. As a matter of fact, children are so good by this age that they will engage productively in enriching their counting routine up to a much later point in development, when they realise and understand the concept of infinity (EVANS, 1980), only by the age of six years.

However, as well as verbal counting, there is also a consensus in the field that even young preverbal babies have the ability to determine the cardinality of sets. That is, infants, as young as neonates, can represent numerosities, but they do not yet have the capacity to express this numerical content in language. This is the conundrum that has triggered much research in developmental cognitive science: how is it possible that young infants have the ability to count in the absence of language, but take so long to nail down the counting system when language kicks in?

Le Corre (this volume) addresses this question, and here, care will be taken not to repeat these issues. Instead, we will focus on a brief review of the two systems of counting that have been proposed in the literature, and for which we have plenty of evidence: an analogue magnitude system (AMS) and a parallel individuation system (PIS). This is relevant for the types of planned experiments for the proposed agenda. Despite the wealth of research to show that infants represent number, the nature of these representations is still very much at the forefront of research today. Most fundamentally, the question remains whether the infants' representation of number contains explicit symbols, in roughly the same way as counting for a four-year-old would involve the use of symbols and would therefore be intrinsically symbolic (e.g., a mental symbol, "$", would correspond to the lexical item "two"). This is a relevant question because it helps us decide on the nature of the process underlying the assignment of numerical tags to numerosities.

The Analogue Magnitude System

This proposal refers to idea that number is represented via a mechanism that encodes number as magnitudes. Some have proposed an accumulator type of mechanism (MECK & CHURCH 1983; WHALEN, GALLISTEL & GELMAN 1999) which represents number as energy pulses in the nervous system. This is an elegant proposal, for which there is plenty of evidence in psychophysics, from nonhuman animals to human adults and children. Meck and Church (1983) were the first to propose that animals represent integer values with a magnitude that is an analogue of number. Suppose that the nervous system has the equivalent of a pulse generator that outputs neural activity at a constant rate, an a gate that can open to allow energy through to an accumulator that registers how much has been let through. When the animal is in counting mode, the gate is opened for a fixed amount of time (say 100 ms) for each item to be counted. The total energy accumulated will then be an analogue representation of number - "--" amount corresponds to a representation of 1, "----", to a representation of 2, "------" to a representation of 3, and so forth and so on. Individuals being counted correspond in one-to-one fashion to tags on a list. The numerical value of any given representation is given by its ordinal position in a series of states of the accumulator: ("--, ----, ------, ..."). The mental tally of the counting process results in an abstract symbol – so, 3 would be represented by "------" in the present example. In addition, a system of this sort will be subject to Weber's Law, a principle in psychophysics that quantifies the perception/representation of change. In the domain of number, research has shown that the standard deviation of numerical estimates increases in direct proportion to the number being estimated. This is called scalar variability. For example, it is easier for us (and animals) to discriminate 8 from 16 than it is for us to discriminate 8 from 12, as it is easier for us to discriminate 2 from 3 than it is for us to discriminate 34 from 35. These psychophysical effects are widespread in the animal kingdom.

The Parallel Individuation System

A second proposal for human counting was put forward originally by researchers in the adult literature on object tracking in the late 1980s, early 1990s. The main idea is that humans represent entities, be it visual objects, auditory stimuli, events, etc., by tracking each entity as an individual. So, for example, an infant of 5 months (and even younger) will establish representations of small collections of objects (even when these objects are concealed behind an occluder) and can reason about the existence of and physical interactions between objects. So, suppose the infant will build a model of the objects behind the occluder, updating the model when new objects are added or when objects are taken away. In this instance, the collections of objects (say, two) are encoded in the process of parallel individuation that enables the representation of one individual, then another individual, as the model is updated from oneness to twoness. Thus, a collection of two objects would be encoded by a representation of the form: "$O_i O_j$", or in the form of any other representation that is equivalent to: "There is an entity, there is a numerically distinct entity, each entity is an object, and there is no other object". That is, two Xs may be represented "$X_i X_j$" or "$O_i O_j$", whereas two Y's may be represented "$Y_i Y_j$" or "$O_i O_j$". In this class of models, the representation of the cardinality of the set is determined by the process of individuation carried out online. In parallel information processing, as entities are represented, the level of processing demand is significantly increased, and therefore, the system is unable to track and tally several entities at once. Numerical representations of collections are stored in short-term memory for access. The literature on psychophysics (e.g., MOYER & LANDAUER,

1967) suggests two curves for numerical processing in number encoding: the first, a somewhat flat curve from numerosities one to four, and an exponential curve from five onwards. If this is the case, then it would make sense to expect humans (and nonhuman animals) to show differences in numerical processing, and indeed, there is now a wealth of evidence to show that human adults, children, infants and animals represent one, two, three (and four) differently on occasions in which the parallel individuation system seems the best candidate to underlie the abilities being tested.

Note that the proposal is for the two systems to work in concert – both systems bound by cognitive processing, in the first, scalar variability, in the second, format. The question that still motivates this research is – in which number processing instances will one system override the other, and vice versa?

The Tikuna language: a brief overview

The Tikuna language is spoken by approximately 70,000 individuals, according to the latest census, who live in Western Amazonia, divided within three countries – Brazil, Peru and Colombia. On the Brazilian side, the Tikuna constitute the largest indigenous group in the country, organised into communities comprised of 117 "aldeias" within 25 areas found in 8 municipalities of the state of Amazonas[4] – the majority along or in the proximity of the Solimões river. If we consider the records as presented by Flores (2018, p. 25), the number of municipalities in which the Tikuna live is presently significantly higher[4]. Soares (second author) has studied the Tikuna language in two of these areas: the Évare I (aldeias Belém do Solimões, Vendaval e Campo Alegre) and the Nova Itália area (aldeia Canimaru). Évare I is located in the municipalities of São Paulo de Olivença and Tabatinga (Amazonas). This area is composed of 47 aldeias, which effectively includes more than half of the Tikuna population in Brazil. Within the Tikuna, there are speakers of other languages who, as minorities, subject themselves to the Tikuna lifestyle.

If one considers the historical-comparative perspective, the Tikuna language is considered an isolated, unique case. Greenberg (1987) considered Tikuna as a member of a supposed branch Macro-Tukano. However, methodological problems such as inaccurate data analyses, and false etimological characterizations, led Greenberg's work to be critically considered as lacking scientific evidence. In recent years, researchers have explored the possibility that Tikuna may be part of the group Ticuna-Yurí (the latter, an extinct language) (CAMPBELL, 1997; CARVALHO, 2009).

Regarding its properties, Tikuna is a language that offers challenges. It is a complex tonal system, in which the phonetic manifestations do not directly present the motivations of the processes that give birth to them (SOARES, 1996a, 1996b, 1998, 1999, 2000b, 2001, 2020). Syntactically, Tikuna presents a system with clitics, asymmetric relationships between subject and object, in addition to an unusual system of temporal marking (SOARES, 2000a, 2007, 2010, 2017).

Most interestingly, it has a particular way of expressing number. There are precise lexical items to correspond to the concepts of 1, 2, 3 and 4. For larger numbers, speakers make use of body parts to aid in the counting: one hand makes five, one hand and one makes 6, a hand and two makes 7, up to 9. Ten is a compound of two hands. The fact that the Tikuna express in language only the numerical concepts up to four could lead to the hypothesis that Tikuna speakers can only compute numerosities up to 4. The question of linguistic relativity in its weakest form would raise the possibility that the human ability for arithmetic would be dependent on language.

A handful of studies have by now attempted to address these questions in languages from indigenous populations which present special attributes as far as expressing numerical concepts is concerned. Here we will particularly focus on three studies that investigated these questions in three languages with very small lexicon of number words (GORDON 2004; PICA, LEMER, IZARD & DEHAENE 2004; PIANTADOSI et al. 2014).

Gordon (2004) investigated another Amazonian group, the Piraha, who express discrete numerosities with specific lexical items up to 3. In a series of experiments, it was found that the Piraha do not use recursive aspects of language to count larger numbers, namely, they do not combine the lexical item for two to count 4. Fingers can be used as supplement, but they are not used consistently and therefore are not precise, but more of an estimative nature. Pica et al. (2004) investigated the Munduruku, another linguistic group in the Amazon, who express discrete numerical concepts up to 5, but are only able to compare large numbers via an apparently estimative system. Given their results, they proposed two systems of counting: a language-based system for small numbers and a language-free system for large numbers. More recently, Piantadosi et al. (2014) investigated a population of Tsimane speakers in Bolivia. The originality of this study lies in the attempt to test children, not adults, 3 to 12 years of age. The results generally show a parallel in the acquisition of the number words for one, two, three and four, but a delay in the acquisition of the number words when compared to a matched population in the USA, namely, the acquisition of number words seems to occur later than in the USA counterpart. Of utmost importance is the finding that there seems to exist a universal across languages, and cultures, in the developmental trajectory in the establishment of numerical concepts, at least, in the comparisons proposed in this article.

The interpretations of such findings, however, are limited for many reasons. First, the informal nature of the testing does not provide definitive evidence for the counting systems proposed in Pica et al. (2004). Second, the linguistic and cognitive approach needs to be expanded to include different numerical abilities in different cognitive/linguistic situations. Third, as most importantly for our purposes here, in none of these studies there was a concern regarding the conceptual development of the number system, namely, how children come to acquire a language-based number system that will eventually allow us as adults to count, estimate, etc. The possibility of developing tasks to test children in phase of language acquisition is exciting – the prospect of addressing the weaker version of the linguistic determinism debate represents yet another, original avenue to bring data to bear on the question of the relationship language-thought.

The proposal of an agenda

Here we propose to further these findings using the Tikuna as our test case. We propose to use three different tasks to assess numerical abilities in two populations of Tikuna speakers, adults and children in phase of language/number acquisition. The tasks are composed so as to encapsulate separately, albeit enabling general conclusions, three different numerical processes which allow for linguistic descriptions/naming. The tasks are inspired by Gordon's (2004) tasks but expand on their application. Tasks will also be modelled on findings by Pitt et al. (2022) who found differences in modelling based on data with the Tsimane, an indigenous population in Bolivia.

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