Numerical cognition among speakers of the Jarawara language: A pilot study and methodological implication

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1 Introduction

Numerous researchers in a variety of disciplines have begun to investigate in earnest a question that has long fascinated linguists and others: to what extent does language influence non-linguistic cognition? The evidence suggests increasingly that, across a variety of cognitive domains, the language an individual speaks affects in very real (though often subconscious) ways their cognition more generally. The evidence in question is based on a variety of experimentally-based studies among speakers of a diverse set of languages. This evidence does not necessarily support the simplest broad Whorfian perspective, at least not in the strong way it is often interpreted according to which speakers of different languages have some largely incommensurable thought patterns. Nevertheless the evidence does suggest that particular linguistic features can serve to meddle with certain non-linguistic cognitive processes or, conversely, augment certain non-linguistic cognitive abilities. (See Wolff and Holmes 2010 for a discussion.)

One example of a linguistic feature whose existence clearly augments non-linguistic cognitive abilities is a set of precise number terms. It remains a matter of some debate, however, how much influence number terms have on basic numerical cognition. (See De Cruz and Pica 2008.) To help resolve this debate, researchers have become particularly interested in experimentally documenting the numerical cognition of speakers of anumeric languages. Only a handful of the 7,000 or so extant languages can truly be considered anumeric, however. (See survey in Hammarström 2010). One language that is claimed to be completely anumeric is Pirahã (D. Everett 2005). This claim has now been substantiated experimentally (Frank et al. 2008). The results in Gordon (2004), Frank et al. (2008) and C. Everett and Madora (in press) suggest convincingly that speakers of this language do not exactly recognize numerosities greater than three. Consider the results presented in Figure 1.

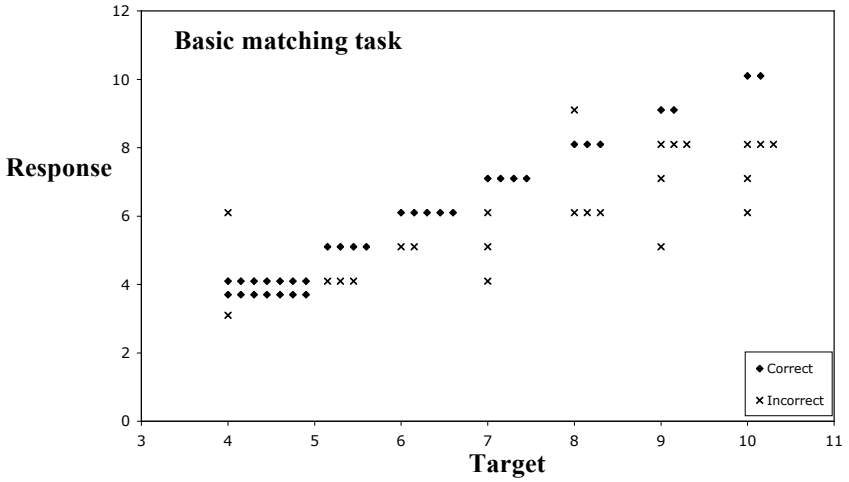

Figure 1: Trial-by-trial results for a basic one-to-one matching task carried out recently among the Pirahã. Taken from C. Everett and Madora (in press).The x-axes plot the number of spools of thread presented for each trial, and the y-axes plot the number of balloons used by the Pirahã participants when attempting to match the target array. Correct responses are marked with a diamond, incorrect responses are marked with an *x*. Multiple correct or incorrect responses for a particular target quantity are staggered.

*The author wishes to thank the Jarawara who volunteered for this study.

As we see in Figure 1, speakers of this anumeric language struggle with the exact recognition of quantities greater than three judging from the evidence in such tasks. For the experiment depicted in the figure, 14 adults were presented with arrays of spools of thread. For each array, they were asked to match the number of spools of thread with their own array of empty rubber balloons. (See C. Everett and Madora [in press] for further methodological details.) Crucially, the performance of the participants deteriorated once the number of stimuli exceeded three. The number and magnitude of errors increased with the number of presented stimuli, in keeping with the utilization of analog estimation strategies (see Gordon 2004), rather than task incomprehension. Performance on similar yet more complex tasks was even worse, according to results in all three aforementioned studies undertaken among the Pirahã to date. For instance, when the speakers are asked to match spools of thread with a line of balloons that is perpendicular to the line of thread (an 'orthogonal matching task'), their performance is deleteriously affected. The same is true when speakers are asked to match an array of thread spools that is only presented for several seconds before being concealed (a 'hidden matching task'). All of these results suggest that speakers of this language that have not been familiarized with number terms struggle with the exact recognition, recollection and manipulation of exact quantities greater than three. The results are consistent with findings on the ontogenesis of numerical cognition that suggest number terms serve a crucial role in allowing for the precise recognition of quantities greater than three. As Carey (2001) notes, for example, number terms help humans to conjoin two innate neurophysiological systems that are apparent in pre-linguistic infants and in other species. These systems are dedicated to the exact recognition of quantities of three or less, and to the approximate recognition of quantities greater than three. Number terms appear to allow for the interaction of these two systems.

As they relate to the notion of linguistic relativity, the findings in studies such as Gordon (2004) suggest simply that an anumeric language profoundly affects the cognition of its speakers, when contrasted to speakers of numeric languages. This suggestion is not immune to criticisms, however. Some have pointed out that it is unclear in the Pirahã case how much the documented quantity recognition patterns are due to linguistic features and how much they are due to other cultural factors. As Casasanto (2005) has pointed out, for instance, this work suffers from the absence of quality control groups. The Pirahã results are contrasted, at least implicitly, with our knowledge of quantity recognition abilities among non-tribal populations. Of course such populations differ in other major respects, including culture, environment, and access to formal education. Casasanto (2005) suggests that research such as that in Gordon (2004) would benefit from the inclusion of experimental results obtained among other tribal groups with similar cultures. Some might counter that there are no cultures that are broadly similar enough to account for such effects, even among Amazonian tribes. Nevertheless, it seemed to us worthwhile to begin to conduct research on numerical cognition among other Amazonian hunter-gatherer groups. At the least, it would seem that the results obtained among such groups would serve as useful relief for the findings on Pirahã. In order to help resolve the debates on relativistic effects on numerical cognition, it would be useful to eventually conduct such work among numerous hunter-gatherer societies with robust number systems, and among the handful of groups with extremely modest systems (see De Cruz and Pica 2008). One Amazonian group said to fall into the latter category, i.e., to have a remarkably modest native number system, is the Jarawara. Our attention was naturally drawn to this group since, according to Hammarström (2010:17), the Jarawara language and other members of the small Arawá family to which it belongs have no number bases. Epps (2006) also notes that this language is anumeric.

The claims regarding anumericity in Jarawara can be traced back to Dixon's (2004:559) extensive grammar:

> It is likely that before contact with Branco culture, the Jarawara did not indulge in counting and did not use lexical numbers. A modern-day conversation such as 'How many fish did you catch?' 'Two (or three or seven or eleven)' simply did not occur.
>
> The language did have the following intransitive verbs: (i) *-ohari(ha)-* 'be alone'… (ii) *-fama-* 'be a pair, be a couple (with)' …
>
> However, on exposure to counting in Branco culture, the Jarawara began to count in their own language. Quite naturally, the meaning of *-ohari(ha)-* has been extended to also serve as a number 'be one', and *-fama-* has taken on the additional sense 'be two'. Other numbers are loans from Portuguese, for example, *terei -na-*

(or *trei -na-*) 'be three', *kowato -na-* 'be four', *siko -na-* 'be five', *tee -na-* 'be ten' (from *três*, *quatro*, *cinco*, and *dez*, respectively).

In other words, Jarawara, like Pirahã, is claimed to be a natively anumeric language. Unlike the case of speakers of the latter language, however, Jarawara speakers have apparently borrowed Portuguese numbers. It is unclear from Dixon's work how systematic this adoption has been, however. What seems clear is that the language lacks a native set of precise number terms. Given Dixon's clear expert assessment based on extensive periods of field research in a Jarawara village, we sought to conduct some basic tasks related to numerical cognition with speakers of this language. We hoped that the results obtained among them could be contrasted with the Pirahã results and further shed light on the cognitive effects of anumeric language.

2 Pilot Study on Quantity Recognition

From the outset, we did not expect to exactly replicate the results obtained among the Pirahã. After all, unlike the Pirahã many (though by no means all) of the Jarawara exhibit some bilingualism. Nevertheless, given the stated long-term goal of better delineating the numerical cognition of Amazonian tribal groups with limited native number systems, it seemed crucial to investigate numerical cognition among this group, since there are only a handful of anumeric languages in the world, and since the Jarawara are also hunter-gatherers without complex native material technology. Furthermore, we were aware that a number of the Jarawara have not had western schooling, particularly older Jarawara, and that the Portuguese-speaking abilities of many are quite limited.

Seven Jarawara adults volunteered to participate in a pilot study on numerical cognition. These Jarawara live in remote villages, though at the time of their participation they were visiting the city of Porto Velho, Rondônia. All seven participants were familiar with Portuguese, though their Portuguese-speaking abilities were limited. As a point of departure for investigating their numerical cognition, we employed the same three tasks used among the Pirahã in C. Everett and Madora (in press): a simple one-to-one recognition task, an orthogonal matching task, and a hidden matching task. The same materials, spools of thread and balloons, were employed. As in the case of the relevant work with the Pirahã, each participant was tested for numbers 1-4, and each participant was tested for at least three numbers from 5-10 (ensuring both lower and higher numbers were tested), for all of the tasks. Completion of the tasks required approximately 30 minutes per subject.

The results obtained among the Jarawara differed markedly from those obtained among the Pirahã. In the case of the one-to-one matching task, none of the seven Jarawara speakers presented any errors. All 31 trials contained correct responses as we see in Figure 2, which can be fruitfully contrasted with the results in Figure 1. The Jarawaras' proportions of correct responses differed significantly from those of the 14 Pirahã tested (unpaired t, $p = 0.000$).

For the orthogonal matching task, only two errors surfaced. These were minor, as evidenced in Figure 3. Here again the disparity in performance between the two tribes was significant, when the Jarawara individuals' proportions of correct responses were contrasted with those described in C. Everett and Madora (in press) for the Pirahã (unpaired t, $p < 0.0001$). We should stress that there are various potential explanations for this discrepancy. One potential explanation is the relative familiarity of Jarawara speakers with borrowed Portuguese number words. Before conducting these tasks, we tested each Jarawara speaker's familiarity with Portuguese number words. Most, though not all, were able to produce the Brazilian numbers for one through ten, but generally with difficulty. Two speakers were unable to provide all of the words without prompting. When asked if they were familiar with the words they failed to produce, however, in all cases they said yes. Another potential explanation is actual math training, which numerous Jarawara have had in Portuguese. The purpose of this study was to start to get an idea whether those who had not had such exposure had difficulty with the tasks. But none seemed to, certainly not to the extent that the Pirahã do.

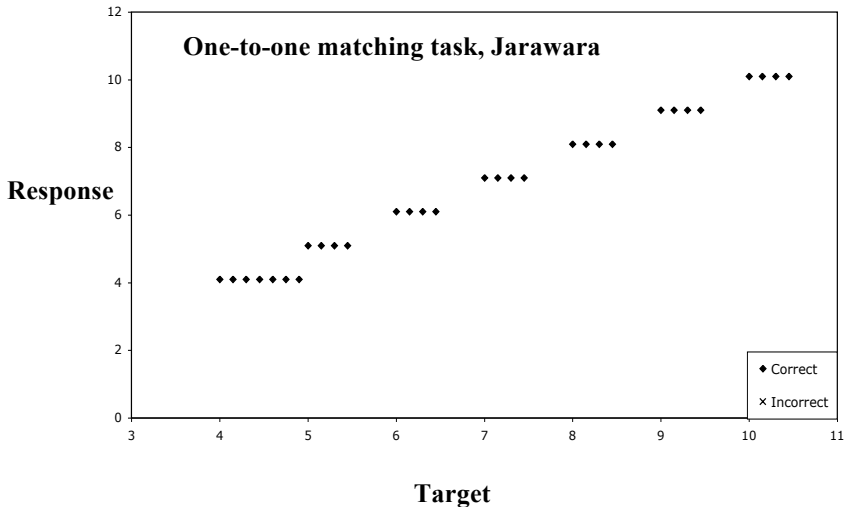

Figure 2: Performance on individual trials for orthogonal matching task, for seven Jarawara.

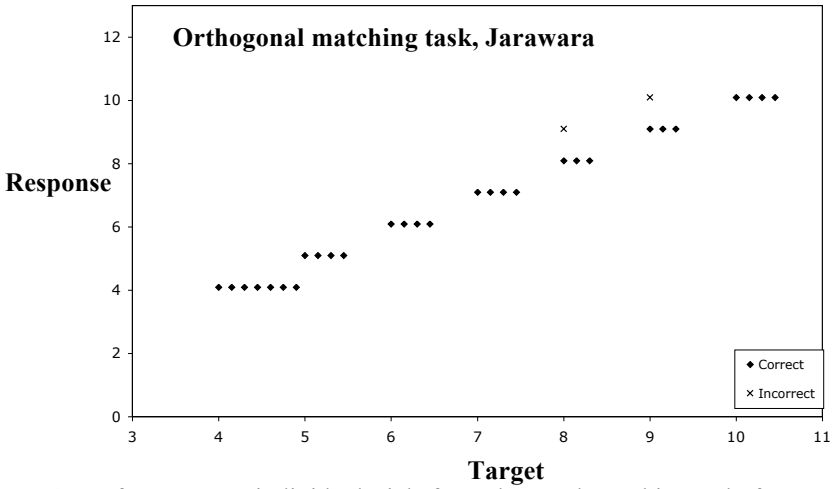

Figure 3: Performance on individual trials for orthogonal matching task, for seven Jarawara.

As we seen in Figure 4, the performance of the Jarawara on the hidden matching task did contain numerous errors, though the majority of responses (30/37) were correct (compared with 24/56 for the Pirahã on this task—see C. Everett and Madora [in press]). Responses for each of the individual trials are depicted in Figure 4. It is apparent from this depiction that none of the responses contained errors in which the number of objects presented by the Jarawara participant deviated more than one in number from the number presented to them. In other words, the magnitude of errors was clearly smaller than the magnitude of incorrect responses in the Pirahã responses as documented in the three aforementioned studies among that group. The Jarawara speakers' proportions of correct responses again differed significantly from those obtained among the Pirahã (unpaired t, $p < 0.001$).

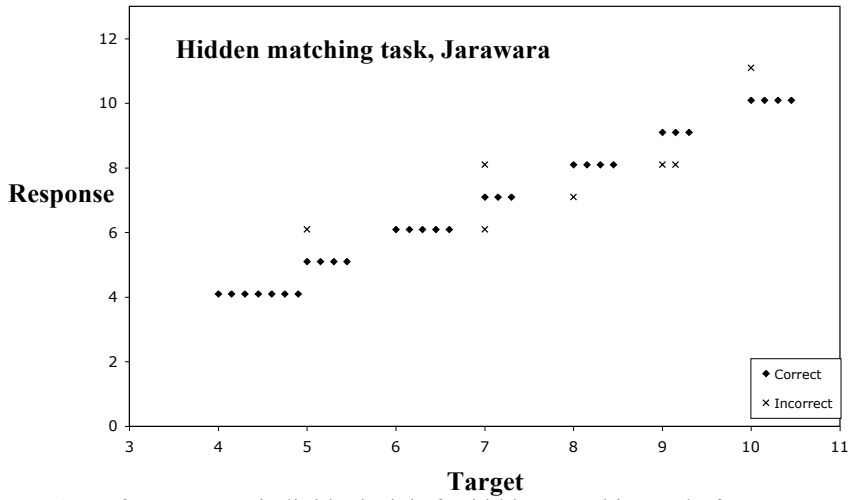

Figure 4: Performance on individual trials for hidden matching task, for seven Jarawara.

Despite their markedly better performance on the tasks vis-à-vis that of the Pirahã, it is worth stressing that the Jarawara responses did contain errors. The ratio of incorrect responses for the hidden-matching task in particular was not insignificant.

At the coarsest level, the significant disparity in performance between these two indigenous cultures could be taken as evidence against the strong relativistic interpretation of the Pirahã data. After all, a quick reading of these data suggests that the native speakers of two putatively anumeric languages differ markedly in their ability to match, mentally transpose, and recall stimuli. Such a straightforward interpretation of the data might even seem plausible at this point, despite the presence of potentially conflating variables already noted. In short, based on the findings in Dixon (2004), the data on the numerical cognition of Jarawara presented here do not seem to dovetail neatly with a relativistic account.

Crucially, however, there is an additional and more pertinent confounding variable that precludes such an 'anti-relativistic' interpretation of the data. We were not aware of this variable at the outset of our pilot study among the Jarawara.

3 New Findings on Number Words

When we began the pilot study on Jarawara numerical cognition, we did not elicit native number words for three to ten, since the literature on this very-well documented language suggests so unequivocally that they do not exist. During the course of this investigation, however, we have actually found incontrovertible evidence for a relatively robust native number system in Jarawara. The evidence that this number system is native to the language (rather than being, say, an adaptation of some other number system) is presented in detail in C. Everett (in press). In this section we merely present the number system and suggest that native numbers are actually common to all Arawá languages.

The native number system described in Table 1 was originally transcribed by a Jarawara man. During the course of the pilot study, I asked him what numbers are available in his language. My assumption was that I would be provided with a list of borrowings. However, he produced the list in Table 1, using the Jarawara orthography. This list was then corroborated independently by another Jarawara man who produced the same words. In fact, when prompted all seven Jarawara participants recognized this number system, though some were unfamiliar with the words for numbers greater than ten. Also, only four of the speakers were able to produce the number words independently. Alan Vogel, who has extensive experience among the people (see Vogel 2003, 2006, 2009), claims that he has heard native number terms occasionally, though Portuguese borrowings are more typically employed.

Numeral	Jarawara term	Numeral	Jarawara term
1	Ohari	11	(yehe) kafama ohari
2	Fama	12	" kafama fama
3	fama oharimake	13	" kafama fama oharimake
4	Famafama	14	" kafama famafama
5	(yehe) kahari	15	" kafama kahari
6	" kahari oharimake	16	" kafama kahari ohrimake
7	" kahari famamake	17	" kafama kahari
8	" kahari fama oharimake	18	" kafama kahari fama
9	" kahari fama famamake	19	" kafama kahari fama
10	" kafama	20	" kafama kafama

Table 1: Cardinal number terms in Jarawara, adopted from Everett (in press).

The relationships among the Arawá languages are delineated in Figure 5. According to Dienst (2008), the languages of Madihá are best classified as dialects (see also Dixon 2004, Anonby and Anonby 2007). Interestingly, close inspections of the dictionaries and word lists of Arawá languages suggest that, in all documented cases, the languages of this family had native number terms. C. Everett (in press) provides the numbers evident in these dictionaries. For our purposes, it is sufficient to note that native number terms are clearly documented for Deni (Koop and Koop 1985), Paumarí (Salzer and Chapman 1997), Banawá (Anonby and Anonby 2007), as well as for the now-extinct Arawá (Chandless 1869). The presence of related number systems in all these languages implies quite clearly that number terms have existed for some time in Jarawara.

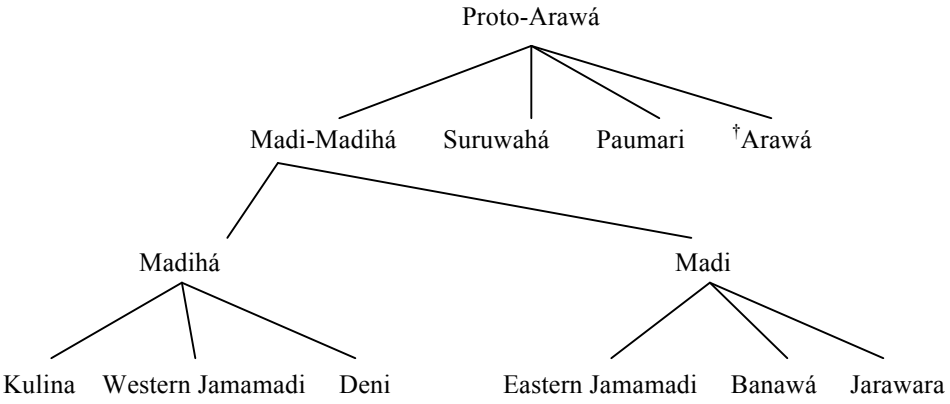

Figure 5: Relationships within the Arawá family, according to Dienst (2008).

At first glance, the results presented in section 2 could appear potentially problematic for the idea that anumeric language has a strong influence on thought by preventing the recognition of exact quantities, as well as their recall and manipulation (see C. Everett and Madora in press, Gordon 2004, Frank et al. 2008). All of the Jarawara participants did well on the tasks, even those less familiar with Portuguese number words. However, given that their language does in fact have native number words, those findings are not at all inconsistent with the notion that number words are a crucial 'conceptual tool' (in the sense of Wolff and Holmes 2010) required for the mere recognition of exact quantities.

4 A Methodological Variable

The claims in Dixon's award-winning (*Leonard Bloomfield Award*) grammar are quite surprising

in the light of our findings. One wonders how he arrived at his conclusions regarding Jarawara numerals. We believe that the most plausible explanation relates to a methodological factor that likely merits greater attention in this sort of research: intra-tribal linguistic variation.

As we noted above, only four of the seven Jarawara participating in our pilot study were able to produce all of the numbers for 1-10 independently (though all claimed to recognize the numbers once I read the list provided by other Jarawara). Interestingly, the three that were unable to produce the entire number list were from the same village, named Casa Nova.

All of the Arawá languages are spoken in the jungles between two major tributaries of the Amazon, the Juruá and the Purús. Jarawara is spoken primarily in two main villages, Casa Nova and Água Branca. There are approximately 50 speakers in each of these villages (out of about 170 Jarawara), whose locations near the western banks of the Purús are depicted in Figure 6. While the speakers of both of these villages maintain contact with Brazilians, there has been a greater outsider presence in the village of Casa Nova in the last few decades. This includes the presence of Dixon himself, whose field work took place in that village.

Figure 6: Locations of principal Jarawara villages.

Given that there is a cross-village disparity in the native number recollection abilities of the Jarawara participating in this pilot study, and given that only those from Água Branca were able to produce all the numbers independently, it is possible that Dixon's errant claims were due to a sampling bias in his data. That is, since he worked primarily with speakers of Casa Nova, he perhaps did not come into contact with native number terms as readily as he might have had his language resource personnel represented both major villages. While this explanation for his claims is tentative, it is the most plausible explanation we can offer.

What is perhaps most interesting about this case is that our interpretation of the results of the pilot study hinges in large part on the fact that we uncovered native number terms. Crucially, we would not have uncovered the terms in Table 1 had we not worked with members of both major Jarawara villages. This suggests that a larger methodological variable is at work here and must be borne in mind when doing this sort of research: the existence (or possibility) of inter-village variation in the maintenance of certain native lexemes. This variable merits consideration especially when documenting lexical domains that are susceptible to varying rates of change across villages, in accordance with disparate patterns of contact with a matrix culture. Given that the adoption of foreign number words is so often motivated by economic transactions, varying rates of outside economic influence on particular villages could potentially influence the rates at which native number terms are maintained in those villages. At the least, the potential for inter-village variation of this sort must be considered. Regardless of the quality of the general research methodology, or the experience of the researcher, possible inter-village variation must be taken into account before arriving at strong claims on, e.g., the absence of a native number system in a

given language.

Finally, it is worth noting that C. Everett and Madora (in press) describe a similar phenomenon among the Pirahã. Specifically, they note that variations in the results of two previous studies on the numerical cognition of the Pirahã are most plausibly due to inter-village disparities in the level of contact of the people with external cultures. I refer the reader to that work for a more detailed assessment. The findings in that study are worth mentioning here, however, since they too suggest the possibility for inter-village variation must be accounted for when documenting numerical concepts among tribal groups.

5 Conclusion

The data presented here serve as an initial delineation of numerical cognition among speakers of Jarawara, and also serve to better describe their previously undocumented native number system, which is being documented more extensively in C. Everett (in press). While my initial goal was to contrast the performance of speakers of two anumeric languages on the relevant tasks, it has become clear that that goal is clearly not within reach at present given that one of the languages in question is not in fact anumeric. As a result, my hope is that the above data and discussion will serve to illustrate a methodological point that is relevant to numerous researchers studying language and cognition in a variety of tribal groups around the world. If our interpretation presented in Section 4 is correct, the findings presented here help demonstrate that intra-tribal variation in the utilization of native lexical forms can influence in significant ways the interpretation of studies on the relationship between language and specific cognitive abilities. Such tribes may have small populations, and an individual village may represent a sizeable portion of the tribe. This can lead to assumptions of uniformity across villages. It is crucial to remember, however, that the histories of these villages, even among hunter-gatherer groups with modest material technologies, may differ in significant ways. Linguistic variation across villages should potentially influence the manner in which relevant experiments should be carried out (at least in some cases), while also influencing the way in which the experimental results obtained should be interpreted.

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