Supporting Online Materials

Materials and Methods

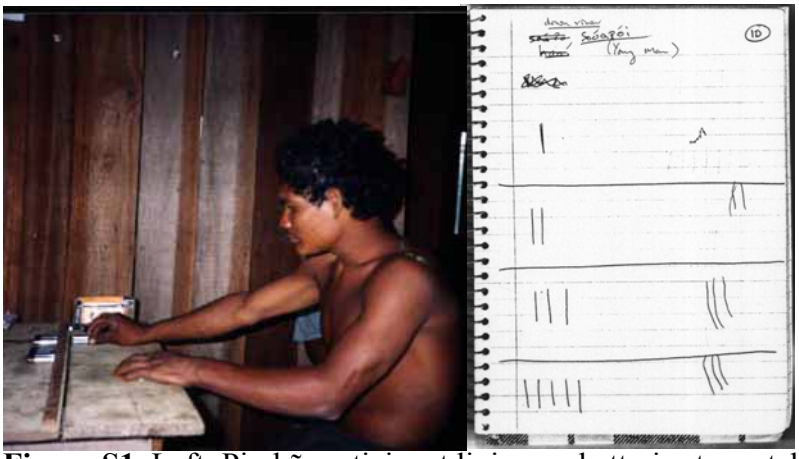


Figure S1. Left: Pirahã participant lining up batteries to match the presented array Right: Notebook used for line copying task

Participants

Participants included 6 adult Pirahã males who appeared to range in age from about 18 to 55 years and one adult female who appeared to be in her early 30s. These represented all of the adult males from the two most upriver villages of the Maici. The children, like most of the women, were inhibited and unwilling to participate. Adult males considered participation to be quite prestigious. They received rewards of food, fishing hooks, beads and other desirable goods for participating. I had visited the two villages in the previous year so that I had already developed a positive relationship with the participants. Recruitment of participants from villages further downriver was not feasible because of the dangers involved in contacting unfamiliar tribe members. Testing sessions varied in length depending on participants' willingness to continue. Most had multiple sessions over the days and weeks that I stayed at the village. The majority of data were collected with four of the participants. Participants (S1 through S7), participated in different numbers of experiments (A to H) and

contributed different numbers of responses to each: **S1** (A=12; B=17; C=16; D=3 E=8; F=15; G=16; H=11); **S2** (A=6; B=21; C=8; D=4; E=8; F=16; G=15; H=11); **S3** (A=6; B=21; C=8; D=6; E=8; F=16; G=17; H=13); **S4** (A=9; B=11; C=9;D=2; E=8; F=27; G=15; H=22); **S5** (D=3); **S6** (A=9; D=4); **S7** (E=5).

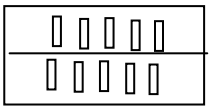
General Procedures

The basic procedure for experiments A through D involved sitting at a table opposite a Pirahã participant with a stick dividing my side from theirs. On my side, I presented an array of objects (either small nuts or AA batteries) and I asked them to place batteries one at a time in 1-1 correspondence with array on my side of the stick and to make it the same (‘aisigiai’). When the participant appeared to be finished, I questioned whether the array was the same. When they assented, I would go on to the next set size. In other tasks, I asked participants to copy the lines drawn on paper, to choose which of two boxes contained candy, and to tell me when a can was empty of nuts (see detailed descriptions below). I always began with small quantities of one and two to get participants started in understanding the task and making it clear that they were to align the batteries in one-to-one correspondence with the target set. All participants picked up on this procedure rapidly and I then randomly selected random other quantities for testing. I made sure that I came back to test the small set sizes to ensure that there were no order effects.

Participants provided 2 or 3 responses for each numerical value over trials. After each response –regardless of whether the answer was correct or not— I gave a cheerful ‘aiyo!’, which means something like “okay!” Feedback was only provided in the nuts-in-can task (E), and the candy-in-box task (F). Tasks were more or less ordered in the sequence given below

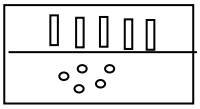
because the later ones often depended on a basic understanding of the task that was made apparent in the simpler tasks. The experiments were carried out over several sessions, the length of each depending on whether participants appeared to be willing to continue.

Specific Tasks



A. One-to-One Line Match

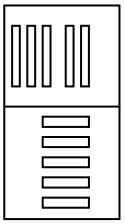
This task was a simple one-to-one mapping of evenly-spaced batteries in a linear array. No memory or mental-spatial transposition was required.



B. Cluster-Line Match

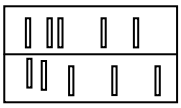
In this task, a cluster (i.e., a no-linear configuration) of ground nuts was presented to be matched by participants with a linear array of batteries. Unlike the first task, it was not possible to simply map the arrays in a one-to-one fashion. Also, this task does not allow participants to simply produce an array that matched in overall "amount of stuff" since the individual items in the target and match sets were of different sizes. Accurate performance would require mapping spatially transposed representations of individual objects from one display into the other. Several participants revealed a mapping strategy by orienting the

batteries so that each pointed to an individual target nut. Such a targeting strategy would be very familiar from their everyday use of bows and arrows for hunting and fishing.



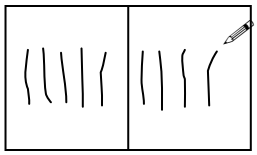
C. Orthogonal-Line Match

Here, the presented array of batteries was perpendicular to the matching array constructed by the participant. Again, matching could only occur on the basis of some mental-spatial transformation of the represented arrays. A strategy of matching on overall length rather than number might be subject to the horizontal-vertical illusion in which vertical lines appear longer than horizontal lines of equal length. Being subject to this illusion would cause overestimation of length.



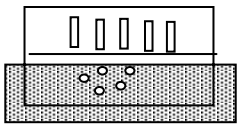
D. Uneven-Line Match

The presentation array was a line of batteries that was unevenly spaced. I originally predicted that this would lead to decrements in performance compared to the simple mapping task. Paradoxically, the uneven presentation of items appeared to benefit participants for quantities greater than seven. The spatial arrays probably cued participants into treating the larger array as a series of smaller chunks of 2 or 3 items that could be matched as such.



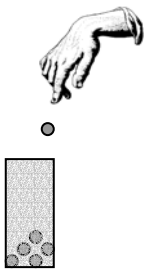
E. Line Copying

This task involved copying lines drawn on a piece paper. Drawing is quite alien to the Pirahã. They do not have regular access to the appropriate materials, and they do not normally engage in any representational activities of any sort. When asked to draw animals, trees, rivers, people, they all end up as simple lines without form. In the line-copy task, the lines in the target panel were drawn on one side of a notepad, and the participant was to draw a similar array in an adjacent panel. This meant that the individual lines were spatially separated from matching lines. In the absence of an ability to represent the numerosity of the set, participants would need to estimate the set size or spatially transpose from the target to the copy.



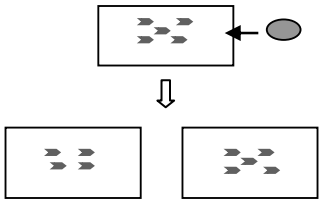
F. Brief Presentation

This was like the Cluster-Line Match task except that the array was seen for only about 1 second, thus requiring a memory-based representation of the array. The procedure involved setting up a nut cluster behind a screen (a letter-sized notebook), rotating the screen forward to reveal the objects and back again to conceal them. All participants had previously performed the cluster-line match task and so the demands were not new except for hiding the display between presentations.



G. Nuts-in-Can

This task also required participants to store the numerosity of an array in memory. In this task, a cluster of nuts was laid out in front of participants for about eight seconds, allowing close inspection and encoding of quantity. The nuts were then put into an opaque oatmeal can. I then pulled out one nut at a time and participants were asked if there were still some nuts in the can ('isaagega') or if the can was now empty ('kaboaba'). If they said it was empty but it was not, or if it was empty and they said it was not, they were shown whether or not there were any nuts left, which was often met with great mirth and laughter whether right or wrong.



H. Candy in the Box

In this task, participants saw a hard candy (a highly favored reward) being placed inside a plastic audio cassette case. On the case was a picture of a number of fish ranging from 1 through 6. The candy was placed inside the cassette case and then it was hidden behind the presenter's back. The presenter then brought his hands forward to reveal 2 cassette cases: The original, and another with either one more or one less fish on the front.

Participants then chose which case they thought contained the candy. If they were correct, they were given the candy. This task again required encoding numerosity in memory. However, the response was a two-choice recall and therefore chance responding was at 50%. This task introduced a reward for good performance, which was very popular.

Brief Ethnology and Linguistic Description

The Pirahã live in small villages of about 10 to 20 people in the Lowland Amazonia region of Brazil along the banks of the Maici River, a secondary tributary of the Amazon River. The tribe has a fluctuating population normally fewer than 200. They represent the last of the Mura family that, at one time, dominated much of the Amazonian region of Brazil. There are no other surviving languages in the Mura family although descendents of the Muras are to be found in the mainstream culture in Brazil. Unlike many Amazonian tribes, the Pirahã have strongly resisted assimilation into Brazilian culture. They live a semi-nomadic hunter-gatherer existence that relies on primitive huts for shelter, dugout canoes for transportation, and bows and arrows for hunting. Food is obtained primarily through hunting and fishing and growing manioc. There is some trading with other tribes, with missionaries and researchers, and with Brazilian traders down river. Trading involves no monetary exchange and no enumeration is required to evaluate goods. Instead, trading tends to be quite idiosyncratic and allows for massive exploitation of the Pirahã by traders.

The Pirahã do not have clear hierarchical social structure except that which emerges through informal male dominance. They have strong beliefs in spirits who are said to pervade the jungle and who interact regularly with the Pirahã. The spirits engage in parallel activities, give names to the Pirahã, take the form of animals, or take their blood away and make them sick or kill them. They engage in spontaneous spiritual activities that include séances and

walking around in circles for hours or even days at a time. They have very complex cosmological beliefs about the origins of life and the spirits that have been documented by MarcoAntoinio Teixeira-Goncalves *(1)*.

The Pirahã Language

The structure of the Pirahã language has been described extensively by Dan Evertt *(2,3)*. The language, while somewhat minimal in vocabulary, has very complex verb structure, common to many Native American languages, where a verb stem might consist of several combined simple motion stems to express more complex meanings. To the verb stem are appended up to15 potential slots for morphological markers that encode aspectual notions such as whether events were witnessed, whether the speaker is certain of its occurrence, whether it is desired, whether it was proximal or distal, and so on. None of the markers encode features such as person, number, tense or gender, which we expect to be encoded based on more familiar languages.

There is no recursion in Pirahã grammar so there are no relative clauses or other embedded constructions. Because of this limitation, certain kinds of comparative constructions cannot be formed. One cannot ask whether one group of objects "has more nuts than the other" because this would require an embedded construction that does not exist in the Pirahã grammar. To make such comparisons simple sentences are juxtaposed as in: "This is big (ogii). That is small (hói)." Again, the word for 'small' ('hói') is the same as the word for 'one'. There is no word for 'number', pronouns do not encode number (e.g., 'he' and 'they' are the same word), and most of the standard quantifiers like 'more', 'several', 'all', 'each' do not exist, although comparable meanings can sometimes be constructed through complex composition of other elements. In general, there is no method of specifically quantifying over

number. They can only refer to the size of an array with dimension unspecified. These linguistic limitations severely limit the kinds of experiments that can be carried out in the language because judgments about relative quantities can be true or false depending on whether they are basing their answers on numerosity or amount of stuff.

The common word for 'many' (baagi-so), is literally a noun derived from a causative form of the verb meaning 'to bring together'. The other Pirahã word for 'many' (aibai) contrasts with a word that means something like 'much' (apagi). This appears to instantiate something like a count/mass distinction, although the exact distributional properties of these terms has not been fully examined in terms of which exact nouns they may or may not modify.

Supporting Figures

The following figures represent the means, standard deviations, and coefficients of variation from Figure 2 in the main text of the article. Data have been broken down by individual tasks (A, B, C, F) and 4 individual subjects from whom most of the data were obtained. Only subjects who provided an average of at least 5 responses per target value were included.

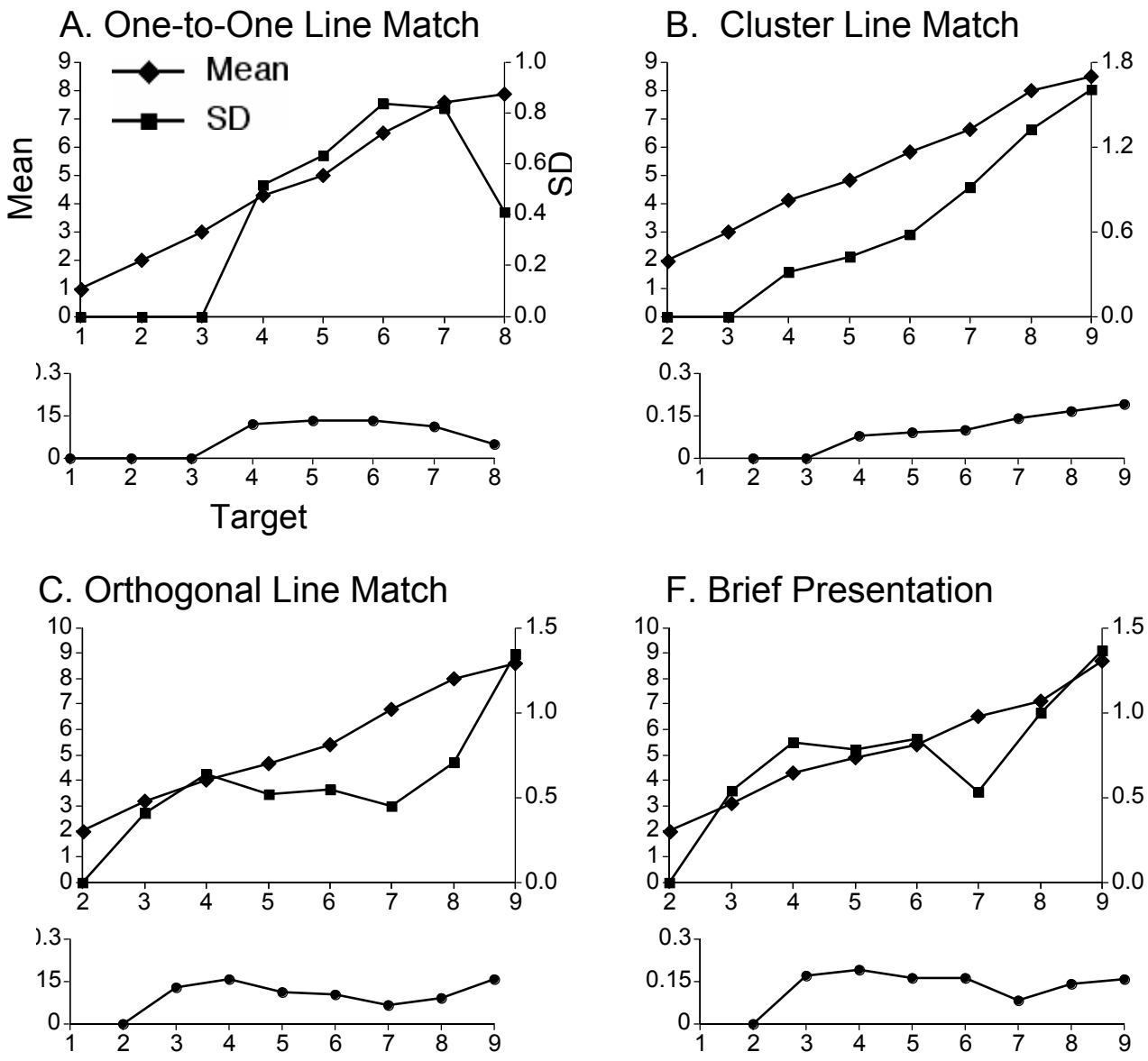


Figure S2 Responses to individual tasks: Mean, Standard Deviation (SD) and Coefficient of Variation (CV)

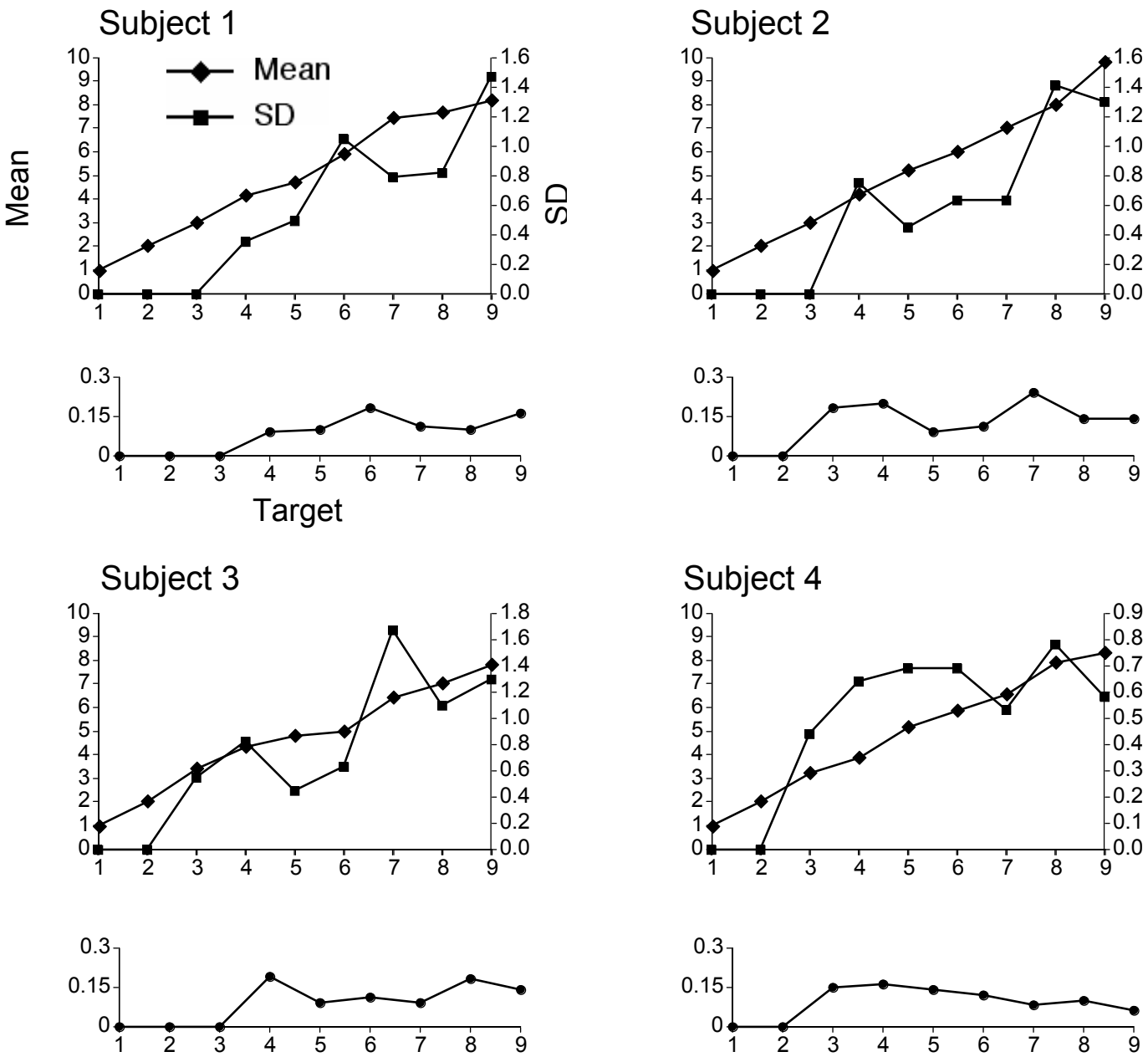


Figure S3 Individual data of 4 participants averaged over tasks A,B,C,F for mean, standard deviation (SD) and coefficient of variation (CV) averaged over tasks. Participants are included if there was a mean of at least 5 responses per target value

Supporting References

1. M.A Teixeira Goncalves,. Nomes e Cosmos. Onomastica Mura-Piraha. (In M. Carneiro da Cunha & E. Viveiros de Castro (Eds) Indios da Amazonia. Univ. Fed. do Rio de Janeiro: Brazil. 1993)

2. D.L.Everett, Cultural Constraints on Language and Cognition in Pirahã. http://lings.ln.man.ac.uk/info/staff/DE/cultgram.pdf

3. D.L Everett,. A Lingua Pirahã e a Teoria da Syntaxe. (Editora de UNICAMP, Campinas, Brazil. 1992)