



## Supporting Online Material for

### Core Knowledge of Geometry in an Amazonian Indigene Group

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Published 20 January 2006, *Science* **311**, 381 (2006)

DOI: 10.1126/science.1121739

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Materials and Methods

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## **1. Material and methods for the multiple-choice test**

### **Participants.**

44 Mundurukú participants were tested. 14 were children (mean 7.9 years, range 5-12; 8 boys), and 30 were adults (mean 51.7 years, range 17-83; 12 men). 26 American children (mean age 7.7 years, range 6-13) and 28 American adults (mean age = 23.4 years, range 17-49) from the greater Boston area were tested at the Harvard psychology department.

**Experimental procedure.** A total of 43 experimental slides, plus two initial training slides, were prepared using PowerPoint software. Each slide contained a 3x2 array of 6 displays which were identified by their light blue square background. The slides probe a hierarchy of basic geometrical concepts that play an essential role in Euclid's Elements or its subsequent topological and metric extensions (see figure 1). Slides were presented in random order on a computer screen using a custom program in Java. Participants pointed to the "weird" or "ugly" image, and the experimenter immediately recorded their response with a mouse click. Indicative response times were thus available, although their precision was not judged sufficient to merit formal statistical analysis. Feedback was only provided on the first two trials, which involved color and orientation and served as training. No other verbal interactions were permitted.

**Additional analyses of bilingualism and schooling.** In our previous work on arithmetic in the Mundurukú, we showed that although some participants could speak some Portuguese and had received some schooling, their performance was essentially unaffected by those variables (*1*). In the present study, out of 14 Mundurukú children, 2 could speak some Portuguese, and 9 had received some schooling. Similarly, out of 30 adults, 7 could speak some Portuguese, another 16 seemed only capable of reciting the automatic series of Portuguese numerals (without necessarily knowing their meaning), while the remaining 7 were strictly monolingual in Mundurukú. Only 5 adults had received a small amount of

schooling. Three analyses demonstrated that these variables had essentially no impact on our results. First, separately for adults and for children, an analysis of variance (ANOVA) was performed on the mean performance scores of the Mundurukú, with factors of bilingualism and slide type (7 levels, as defined in figure 1). Whether bilingualism was defined as an all-or-none variable (absent/present) or as a three level variable (absent/numerals only/present), the results revealed only a main effect of slide type ( $p < 10^{-6}$  in both children and adults), but no main effect of bilingualism ( $p > 0.18$ ) nor any interaction ( $p > 0.19$ ). Second, another ANOVA with factors of age (children or adults), schooling (present/absent), and slide type (7 levels) again revealed only a main effect of slide type ( $p < 10^{-15}$ ), but no other main effect ( $F < 1$ ) or interaction ( $p > 0.11$ ). Third, we redid all the analyses reported in the main text while excluding any participant with a suspicion of schooling or bilingualism, without any significant change in the results.

## **2. Material and methods for the map test**

**Participants.** 31 Mundurukú participants were tested. 10 were children (mean 7.2 years, range 5-11; 6 boys), and 21 were adults (mean 48.7 years, range 25-74; 5 men). All but two adults were monolingual, and only 2 adults and 4 children had received a little schooling. We felt that those subgroups were too small for a formal analysis of the effects of schooling and bilingualism. However we verified that the results were not qualitatively changed when participants who showed hints of bilingualism or schooling were excluded from the analysis. An additional 46 American participants from the greater Boston area were tested at the Harvard psychology department. 17 were children (mean 7.4 years, range 4-12; 10 boys) and 29 were adults (mean 28.7, range 18-57; 10 men).

**Experimental procedure.** Mundurukú participants were tested individually in an outdoor open space or in a large indoor space (an ANOVA indicated that performance did not differ across these two groups). Most American participants were tested outdoors, on the

Harvard campus; in bad weather, a few were tested in a large indoor space. To introduce the task, we first presented a picture of a single red square with a star to participants, while a red box was placed in an open space behind them. We asked them to locate the star in the picture and then to find an object in the box. After participants located this object, they were presented with four trials in which the “map” consisted of a picture of a red square and a grey circle, one of which was starred, while a red box and a grey can were placed behind them with an object hidden in the appropriate container. Participants were allowed to search for the object and, if they failed to locate it on the first attempt, they were asked to again locate the star on the map and then search again for the object. In this training period, the geometrical relationships in the map and the array provided no usable information; only the shape and color of an individual form specified the location of the hidden object.

For the actual experimental trials, four different configurations of containers were tested in fixed order (see figure 2C): a right or isosceles triangle, with three identical circular cans or with one distinctive red box. Six trials were presented in each configuration. The maps were always presented horizontally, while the participant turned his or her back to the environment (figure 2A). Maps could be presented in three different orientations, such that the map and the environment were aligned as seen from the top (allocentric condition), aligned relative to the observer (egocentric condition), or at a 90° angle from these alignments (rotation condition).

### 3. Main terms used to refer to arithmetical, geometrical and spatial concepts in Mundurukú<sup>1</sup>

The following list of words was compiled with the help of several native Mundurukú informants. Tentative English equivalents and, in some cases, etymologies are provided, although we are aware that a systematic experimental study would be needed to determine the genuine referents of those words. We previously conducted such an experimental study for number words (1), and plan to conduct along the same lines a similar study of geometrical and spatial terms in a forthcoming mission (for a similar approach, see reference 2). We could not identify any non-metaphorical terms for other basic concepts of geometry such as triangle, rectangle, square, parallel, right angle, vertical, horizontal, oblique, etc., and our informants insist that the Mundurukú language does not possess such words.

#### 3.1. Arithmetical terms

##### Number words<sup>2</sup>

pũg ma	One (Literally “exactly one”)
xep xep	Two
ebapũg	Three (Literally “your (two) arms + one”)
ebadipdip	Four (Literally “the most of your (two) arms”)
pũg pũgbi	Five (Literally “one handful”)
xep xep pũgbi	Ten (Literally “two handful”)
ebapũg pũgbi	Fifteen (Literally “three handful”)

##### Quantifiers and other expressions of quantity

pũg pũg	Some
pũg pũg pũg	Some
ade	Much
adesũ	Rather much (Literally “much of x”)
ade ma	Really much
ade jijã	Very much
adede	Most
adedem	All
adeũ	Few (Literally “not a lot”)
ade'ũm	Few (Literally “not a lot”)
soat	Every, each
bit	contrastive focus marker (literally “as opposed to”)
pebit	Which amount
boũũn	Extent, size, distance, time... (typically accompanied by two-hands gesture defining a certain extent)
peboũũn	Which size/distance/time
bũrũ	Quantity
iburũm	Quantity of
pebũrũ	How much, how many (Literally “which quantity”)

<sup>1</sup> This part of our work was performed in consultation with André Ramos (Funai) and Gessiane Picanço, without the encouragements of whom it could not have been achieved.

<sup>2</sup> Previous research (Pica et al., *Science*, 2004) has established that all terms refer to an approximate range of numerosities, with the possible exception of the first three number words, and that large number words ( $\geq 10$ ) are rarely used.

### **Ordinal words**

koap	First
awap	Before, ahead (Literally “the one (who comes) ahead”)
no mu ju	After, behind (literally “the one (who comes) behind”)

### **Comparatives**

bodi	More (than)
buxim	Close to (Literally “related to”)
ijo’i	Equal (Literally “similar to”)
waru	Different

### **3.2. Geometrical terms**

#### **Figures**

iroyruy’at	Curved figure, circle
iwaketkut’at	Curved figure

#### **Points and lines**

yabi	Dot, point, beginning, end (literally “the mouth of the round thing”)
ibucũg	Curve, line (literally “his straight finger”)
kadi	Side (literally “bank (of a river)”)

#### **Proportions**

i’in	Part of
i’in pũg	One part of
ipidase	Center, middle, half (literally “on the mouth/skin of the earth/ground”; The earth/ground occupies the middle layer of the universe according to Mundurukú cosmology)
ipidasesu	Right in the middle
ipidasese	Quarter (reduplication of last syllable of ipidase)

### **3.3. Spatial terms**

#### **In/out**

badi	In
be	In, at
be badi	Inside
bodi	Outside, on the side

#### **To/from**

be	To
bewi	From

#### **Above/below/on**

ti ot	Below, under (literally “the place of the water”)
je je	Above
ase	On, hanging above

### **In front/behind**

edopabe  
ti ot pe

In front of (literally “at your face”)  
Behind (literally “at the place of the water”)

### **Left/right**

iba’at  
iba’at kadi  
iba’at ũḡ’at  
iba’at ũḡ kadi

Right side of a person (literally “the one who is at his (right) arm”)  
Right side of an object (literally “on the side of his (right) arm”)  
Left side a person (literally “the one who is not at his (right) arm”)  
Left side of an object (literally “not on the side of his (right) arm”)

### **Here/there**

bodiku  
bodiweku  
bodimaku  
bodimaweku  
ḡoku  
iboce  
ibocewi  
ijoce  
ijocewi

Over there (literally “right over this side”)  
From over there (literally “from right over this side”)  
Exactly there (literally “exactly over this side”)  
From exactly there (literally “from exactly over this side”)  
Right there in front of me  
There (literally “the place over there where he is”)  
There from (literally “from the place over there where he is”)  
Here (literally “the place here where he is”)  
Here from (literally “from the place where he is”)

### **Near/far**

ijasũn  
wuy jijã

Near  
Far

### **Directions**

kaxi jem ap  
kaxi a cap  
tiakay  
deim

Sunrise, east (literally “the place from which the sun rises”)  
Sunset, west (literally “the place at which the sun declines”)  
Upstream (literally “to the water”)  
Downstream (literally “the place of those who leave downstream”)

### **Deictics**

ija  
ijop  
iju  
ixe

This one (literally “this one within hand range”)  
That one (literally “that object on the ground”)  
That one (literally “this one (leaned) within hand range”)  
This one (literally “this one close by that I am speaking about”; foreground or topic of discourse)

#### ***4. References***

1. P. Pica, C. Lemer, V. Izard, S. Dehaene, *Science* **306**, 499 (Oct 15, 2004).
2. S. C. Levinson, S. Meira, and the language and cognition group, *Language* **79**, 485 (2003).