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A universal developmental path in the construction of exact number concepts



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INTRODUCTION In the first years of life, conceptions of exact numbers develop gradually, as children are exposed to number words, and three milestones have been described:
1- understanding that counting is a tool to assess quantities (age ~3½ years)
2- mapping number words to numerical quantities outside of counting situations (age ~4½ years)
3- understanding that addition/subtraction are essential to the structure of the set of integers (age ~8 years)

PARTICIPANTS We studied a group from the Amazon, the Mundurucu [see Pica et al. 2004]. Mundurucu speak a language with a restricted number lexicon. They all have some experience with Portuguese number words, although the level of bilingualism or instruction is very heterogeneous.

Twenty-seven participants (mean age 31.7 years, 7 to 75; 16 females) were tested on the Give-a-number task, the Symbolic Comparison task, as well as the Number-Space task.

Is this developmental path dependent on the input western children receive for learning numbers?

TASKS

Give-a-Number Task [after Wynn, 1990]



"give me three seeds!"
Stimuli: um, dois, quatro, cinco, sete, nove, dez

Comparison Task [after Le Corre, under review]

"which is more, five or six?"

Stimuli
Small vs. small: um/dois, dois/tres
Small vs. large: um/cinco, dois/cinco, dois/nove, dois/dez, tres/quatro, tres/nove, tres/dez
Large vs. large: quatro/cinco, cinco/sete, cinco/dez, nove/dez

Number-Line Task [after Siegler & Opfer, 2003] [see Dehaene et al., 2008]



"Where does five go on this line?"



Stimuli: um, dois, tres, quatro, cinco, seis, sete, oito, nove, dez

PATTERNS OF PERFORMANCE IN WESTERN CHILDREN

Age < 3 ½: "Subset knower"
Can produce sets for numbers up to 1, 2, or 3;
Give the same quantity for all numbers larger than this upper limit.

Age > 3 ½: "Counter"
Can produce sets for any number in their counting range.

Children understand the order principle in the counting list **1 year after** they become able to use counting to produce sets.

Age < 4 ½: "Non- Mapper"
Can compare two small numbers (e.g. 2vs3), or a small number vs. a large number (e.g. 1vs8).
Fail at comparing two large numbers (e.g. 6vs10).

Age > 4 ½: "Mapper"
Can compare any pair of numbers.

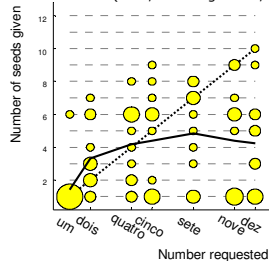
For a line flanked with **arabic numbers** and the scale **1-100**:

First grade: compressed mapping
Placing consistent with the order of the numbers, with more space devoted to the small numbers.

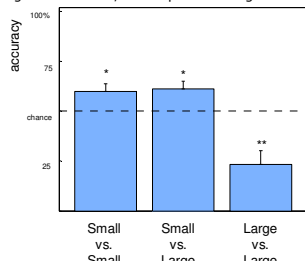
Third grade: linear mapping
Numbers placed evenly.

The performance of the Mundurucu across tasks follows the same pattern as in western children: **None of the participant succeeded at the comparison task while failing at the give-a-number task.** Moreover, the patterns of failures in each task reproduced the failures observed in western children.

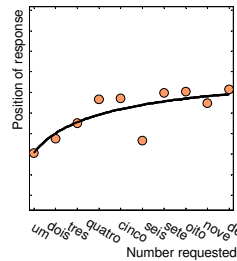
Non-counters (N=8, mean age 39.3, 6 females) (selection: on give-a-number, the slope is non significant on numbers >4):



linear regression on individual responses for numbers larger than 4; test of the slope vs. zero: **8/8 failures**

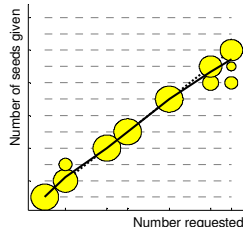


binomial test of individual responses vs. chance level (50%): **8/8 failures**

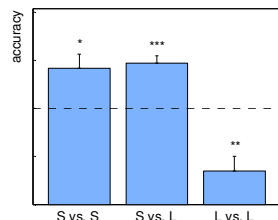


Responses essentially flat
Regression with two regressor, linear and logarithmic: $R^2=0.52$
No significant effect of either regressor ($ps>0.24$)

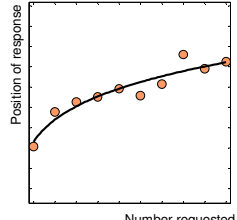
Non-Mappers (N=8, mean age 28.6, 4 females) (selection: on give-a-number, the slope for numbers>4 is significantly positive + at chance overall for comparison):



linear regression on individual responses for numbers larger than 4; test of the slope vs. zero: **8/8 successes**

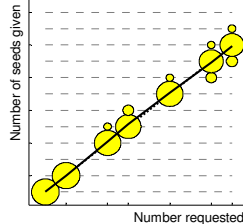


binomial test of individual responses vs. chance level (50%): **8/8 failures**

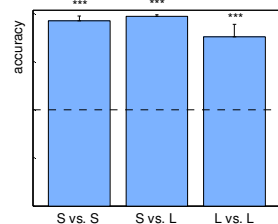


Responses essentially compressed
Regression with two regressors, linear and logarithmic: $R^2=0.87$
 $P_{lin}>0.74$
 $P_{log}=0.070$

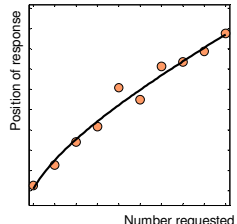
Mappers (N=11, mean age 28.5, 6 females) (selection: on give-a-number, the slope for numbers>4 is significantly positive + significantly better than chance overall for comparison):



linear regression on individual responses for numbers larger than 4; test of the slope vs. zero: **11/11 successes**



binomial test of individual responses vs. chance level (50%): **11/11 successes**



Responses essentially linear
Regression with two regressors, linear and logarithmic: $R^2=0.97$
 $P_{lin}=0.013$
 $P_{log}=0.093$

CONCLUSION Despite huge differences in the exposure to number words (content of input and age of exposure), Mundurucu follow the same developmental path in the acquisition of Portuguese numerical symbols than western children, both within and across tasks. This result suggests that the progression across the stages of the acquisition of number words is not dependent on the input received or of the age of the participant. Rather, this path seems to be constrained by some universal laws of the human mind.

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