Intuitions for Multiplication in Amazonian Adults and in U.S. Adults and Children
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INTRODUCTION

Success at non-symbolic addition and subtraction has been documented with diverse populations: preschool children, occidental adults (in conditions preventing counting), and also an indigene group from the Amazon, the Mundurucu, who speak a language with a restricted number lexicon (Barth et al., 2005; Pica et al., 2004). In all these populations, performance shows a characteristic ratio effect: the sums and differences that participants estimate are approximately, and the range of uncertainty increases for larger numbers.

Studies of brain-damaged patients (Lemer et al., 2003), brain imaging (Dehaene et al., 2003), or task interference (Lee & Kang, 2002) suggest that multiplication and division, on the contrary, may be mediated by language and rote-learned tables. Nevertheless, the existence of a universal capacity for nonsymbolic multiplication has not been investigated directly.

Here, we investigated whether multiplication is part of humans’ universal knowledge about numbers. We presented computer animations illustrating non-symbolic multiplication problems to three different populations: US adults, Amazonian Adults, and US children at two ages, before and during the first years of learning multiplication (respectively Preschool-1st grade, and 3rd-5th grade).

DESIGN, BASIC RESULTS

<table>
<thead>
<tr>
<th>age</th>
<th>Number of trials</th>
<th>Product sizes (n1*n2)</th>
<th>Comparison ratios (n1*n2/n3)</th>
<th>Comparison to Chance (T)</th>
<th>Effect of comparison ratio (ANOVA)</th>
<th>No effect of product size (ANOVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US adults (N=16, 9 females)</td>
<td>34.3y (19-58)</td>
<td>36, 49, 66, 94 49,510, 7,10, 10,5 64, 811,8, 11,6 81, 712, 9,9, 12,7</td>
<td>1.2, 1.5, 2.0</td>
<td>82.3%, P&lt;0.0001</td>
<td>P=0.0001</td>
<td>F&lt;1</td>
</tr>
<tr>
<td>Mundurucu adults (N=12, 10 females)</td>
<td>40.8y (17-75)</td>
<td>36, 49 (cf above)</td>
<td>1.2, 1.5, 2.0</td>
<td>70.8%, P=0.0028</td>
<td>P=0.029</td>
<td>F=1</td>
</tr>
<tr>
<td>US Preschoolers, Kindergardeners and 1st graders (N=18, 11 females)</td>
<td>6.7y (5.0-7.6)</td>
<td>36, 49 (cf above)</td>
<td>1.2, 1.5, 2.0</td>
<td>72.7%, P=0.00014</td>
<td>F=1</td>
<td>F=1</td>
</tr>
<tr>
<td>US 3-5th graders (N=16, 11 females)</td>
<td>9.8y (8.1-12.2)</td>
<td>36, 49 (cf above)</td>
<td>1.2, 1.5, 2.0</td>
<td>81.3%, P&lt;0.0001</td>
<td>P=0.071</td>
<td>F=1</td>
</tr>
</tbody>
</table>

All groups performed well above chance. Except for the younger US children, performance followed the same pattern as in the addition/subtraction tasks: effect of comparison ratio, no effect of product size.

How did participants use the numeric information about n1, n2?

Could participants have responded based on the range of the probe (n3) alone, instead of computing the multiplication?

Extending the previous analysis, we computed the subjective estimates of the operation separately for the different decompositions of the products (eg 4*9 vs. 6*6 vs. 9*4). The following graphs depict these estimates in function of n1 alone, n2 alone, or n1*n2.

CONCLUSION

Contrary to addition, intuitions for multiplication are not universal in humans. Although US Adults can multiply sets of numbers quite accurately, and US children show hints of this ability, this competence is not fully present in another culture, the Mundurucu. Instead of performing a mental multiplication on two numbers, Mundurucu participants approximated the multiplication based on only one of the two operands, given, which they scaled by a constant factor. These results highlight both the limits and the possibilities of intuitive arithmetics: Multiplication of two numbers is not universally present in humans, but scaling by a constant factor seems to be (Barth, 2008).

In occidental populations, intuitions about multiplication may start developing even prior to formal instruction with multiplication. Therefore, the Mundurucus’ limitation with multiplication may not be related to a lack of instruction with multiplication per se, but to more basic differences pertaining to the representation of sets.