Processing negative numbers by transforming negatives to positive range and by sign shortcut

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1 Introduction

Analogue magnitude system gives our numerical competency: it is a system processing magnitudes (Dehaene, 1997). Analogue magnitude system is used in comparison, estimation and approximate calculation tasks. The indicator of its activation is **distance effect**: the closer the two numbers are, the more difficult it is to compare them and the larger their numerical distance is, the less time is needed to process them (that is why we compare 1 and 9 faster than 4 and 5).

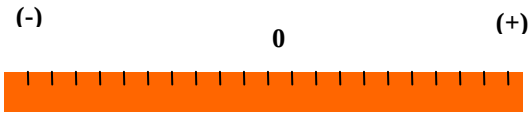
Analogue magnitude system is a **phylogenetically old system,** animals and infants also have it (e.g. Dehaene, 1998). Could it process such newer cultural phenomena as negative numbers?

2 Hypotheses

To answer this question, three different explanations seem to be reasonable.

A) Extended representation

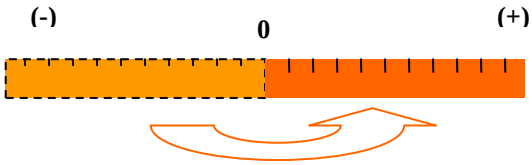
Analogue magnitude system handles negative and positive numbers in a single system. Negative numbers take place on the left side of the number line and positives on the right side.



Extended representation on the analogue magnitude system

B) Mirroring mechanism

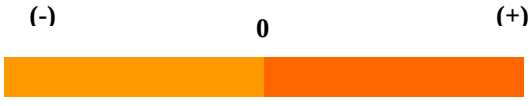
Analogue magnitude system could not handle negative numbers alone, only positive numbers. That is why an **assistant mechanism mirrors negative numbers on the positive number line** and the analogue magnitude system processes their absolute values.



Mirroring negative numbers on the positive analogue magnitude system

C) Sign shortcut

Processing negative numbers does not always need to be assisted by analogue magnitude system. When we compare two numbers having different signs **we can make decisions based merely on the signs**: a minus sign always means a smaller number than a plus sign.



Sign shortcut for processing different-signed numbers

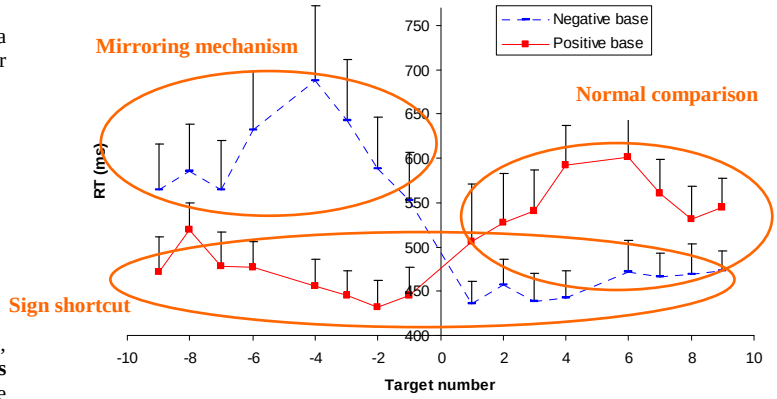
3 Methods

Subjects compared target numbers to base numbers. Target numbers were numbers from -9 to 9, except -5, 0 and 5, appearing on the screen, one at a time. Base numbers appeared in the instructions. They were numbers -5 and 5.
The positive numerals included the plus sign (e.g. "+4") to equal the visual complexity of negative and positive numbers.

16 undergraduate students (3 males, 13 females) participated in our study – later three participants were excluded from the analysis due to high error rates.

4 Results and discussion

We found **significant distance effect in same-sign comparison**: negative base–negative target comparison $t(12)=5.789$, $p<0.001$, positive base-positive target comparison $t(12)=6.049$, $p<0.001$. **Different-sign comparison had no distance effect.**



Reaction time pattern of negative (-5) and positive (5) base comparison

Negative base-negative target comparisons were about 50 ms slower than positive base-positive target comparisons ($t(12)=3.137$, $p=0.009$)**.** There was no difference between negative base–positive target and positive base–negative target comparisons ($t(12)=-1.66$, $p=0.12$).

From these results we conclude that **in same-sign comparison subjects used magnitude comparison** (distance effect, similar reaction time patterns).
Comparing negative numbers involved mirroring mechanism and this caused the slower reaction time.
Different-sign comparison showed no distance effect because it **did not involve magnitude processing**. Furthermore, comparing different-sign numbers took the same time of processing, independently of the sign of the base number. **It implies sign shortcut**: subjects were able to make comparison decision only by seeing the signs.

5 Summary

(1) **Comparing different-sign numbers we use a sign shortcut mechanism** without using analogue magnitude system and (2) **comparison of same-sign numbers takes place on analogue magnitude system**: comparing of positive numbers is based solely on magnitude system and **comparing of negative numbers involves a mirroring mechanism** which turns negative numbers to the positive range and after comparison numbers are formed back to the negative form. **Culturally new phenomena – negative numbers – can be processed by a phylogenetically old system combined with subsidiary mechanisms, sign shortcut strategy and mirroring mechanism**.

6 References

Dehaene, S., Bossini, S., Giraux, P. (1993). The mental representation of parity and mental number magnitude. Journal of Experimental Psychology: General, 122, 371-396.
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