Representation of multi-power numbers in preschool children

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1 The effect of number notations in numerical processing

	Sign-value notation Roman example: XXIII	Place-value notation Indo-Arabic example: 23
Noting the powers (e.g. 1, 10, 100 in a base 10 system)	Symbol X means ten I means one	Position □_ (left position) means tens _□ (right position) means ones
Noting the quantity within a specific power	Quantity of symbols ●●● means three ●● means two	Symbol 3 means three 2 means two

- In a previous work it was found that **adults were faster and more accurate** in comparison and addition tasks **in sign-value notation** than in place-value system (Krajcsi and Szabó, submitted).
- To study the effect of former experience and representations, in the present study we tested preschool children, who have less experience and their experience is more quantifiable.

2 Artificial number notation paradigm

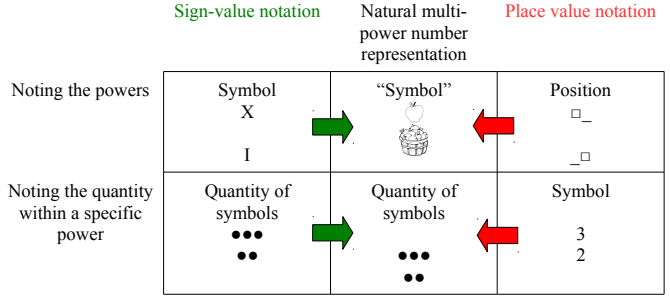
- Base 4 instead of base 10
- New symbols (e.g. 0-Ł, 1-Ø, 2-Đ, 3-И, 4-Я, 16-Ч)
- Comparison task

	Example stimulus with the meaning of the stimulus	
Sign-value notation	ЯЯØØØ (4)+(4)+(1)+(1)+(1)=11	ЧЯЯØØØ (16)+(4)+(4)+(1)+(1)+(1)=27
Place-value notation	ĐИ (2)*4+(3)*1=11	ØĐИ (1)*16+(2)*4+(3)*1=27

3 Natural multi-power number representation

Why is sign value number notation easier to process than place value notation?

- Multi-power number representation originally **might rely on object representation and object enumeration processes, forming a natural multi-power number representation**.
- The structure of sign value notation is more similar to this number representation than the structure of place value notation, thus the transcoding is easier.



This model for multi-power numbers **can be seen as an extension of McCloskey's abstract model** (McCloskey, 1992). The model offers an alternative to the verbal representation and Arabic visual form proposed by Dehaene (1992).

4 Methods

Participants

- 45 participants (24 girls, 21 boys)
  - Mean age 6-5, range 5-8 to 7-5

Number reading task

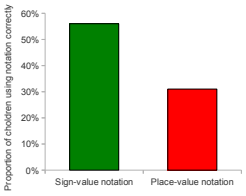
- Single-digit Indo-Arabic numbers (1-9)
- Multi-digit Indo-Arabic numbers (11-29)
- Roman numbers (1-9)

Comparison task

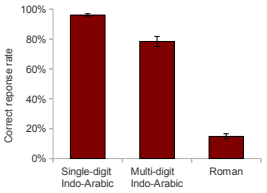
- Compare two multi-power numbers
- Sign-value and place-value notation conditions
- Procedure
  - Learn the symbols for the notations
  - Practice comparison until rules are understood
  - Comparison trials, monitoring incorrect rule use

5 Results

1. Sign-value notation is easier to learn for preschool children.



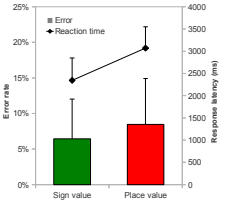
2. Relatively high Indo-Arabic reading performance, while no Roman digit reading.



3. Correlation between Multi-digit Indo-Arabic number reading error rates
   - and sign-value comparison error rate, r(45)=0.356, p=0.017,
   - and place-value comparison error rate, r(42)=0.307, p=0.048

Number notation effect does not depend on former experiences.

4. Error rate and RT within 20 children who successfully learned both notations. Sign-value number performance is better.



6 Conclusion

1. **Sign value notation can be more easily applied** than place value notation for multi-power comparison **irrespective of former experience** with Indo- Arabic notation.
2. While **natural multi-power representation is available in 6 years old children**, place-value notation requires more abstraction that makes it difficult for them to learn Indo-Arabic notation.
3. There is a debate in the literature whether the abstract concept of natural numbers develops from object tracking system (Carey, 2009), analogue magnitude system (Piazza, 2010) or both (Spelke & Tsivkin, 2001). **Our result is consistent with the object based natural number representation**.

7 References

Carey, S. (2009). The Origin of Concepts. Oxford University Press, USA.
Dehaene, S. (1992). Varieties of numerical abilities. Cognition, 44, 1-42.
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Spelke, E. S., & Tsivkin, S. (2001). Language and number: a bilingual study. Cognition, 78(1), 45-88.