Effect of Physical Affordances of Manipulatives on Children’s Number Representation and Numeration Understanding

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Manipulatives and Mathematics Learning

- Positively impact learning and transfer in children without difficulties (Carbonneau et al., 2013)
- Positively impact learning in children with mathematics difficulties (Lafay et al., 2019)

- But not always!
Manipulatives and Mathematics Learning

What impacts learning with manipulatives?

- Environment: Instruction (Moyer, 2001; Osana et al., 2018)
- Object itself (e.g., McNeil et al., 2009; Osana et al., 2018)
- Learner (e.g., Petersen & McNeil, 2013)
Manipulatives and their Physical Features
Importance of base-ten number system

- Place-value understanding predicts future arithmetic performance (Dietrich et al., 2016)

- But 27% of second-graders still have difficulties understanding place value (Gervasoni & Sullivan, 2007)
Objectives

▪ To examine the physical affordances of manipulatives on children’s number representation and numeration understanding

▪ To compare the impact of physical affordances on two groups of children: with and without mathematics difficulties
Study Design

3 object-type conditions

1. Pretest
2. Intervention
3. Posttest
Focus of Present Study

3 object-type conditions

1. Pretest
2. Intervention
3. Posttest
Participants

122 second-graders

- French-speaking
- Recruited in 12 urban schools in Montreal
- 66 boys and 156 girls
Participants

Without mathematics difficulties

\[ N = 94 \]

TTR > 25\textsuperscript{th} percentile

With mathematics difficulties

\[ N = 29 \]

TTR < 25\textsuperscript{th} percentile

Tempo Test Rekenenen (TTR)

Geary, 2013; Lafay et al., 2015
Object-Type Conditions

Detachable & countable (D-C)

Non-detachable & countable (ND-C)

Non-detachable & non-countable (ND-NC)
Measures

1. Representation Task
   - Representation of numeral with manipulatives
   - Four items: Two 2-digit and two 3-digit
   - Two scores:
     - (a) Accuracy of representation
     - (b) Linking representations
Measures

2. Symbolic Decomposition Task

- Symbolic numbers $\rightarrow$ decomposition
- 20 items: Ten 2-digit numbers and ten 3-digit numbers

![Diagram showing symbolic decomposition of the number 12]
Results

Accuracy of Representation

Group: *p < .001*
Object Type: *p = .156*
Group x Object Type interaction: *p = .076*
Results

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Group: $p < .001$
Object Type: $p = .071$
Group x Object Type interaction: $p = .016$
Symbolic Decomposition Task

Portion of sample ($N = 55$):

- D-C ($n = 19$); ND-C ($n = 17$); ND-ND ($n = 19$)
- Without diff. ($n = 44$); with diff. ($n = 11$)
Results

Symbolic Decomposition Task (N = 55)

Group: \( p < .001 \)
Object Type: \( p = .173 \)
Group x Object Type interaction: \( p = .948 \)
Summary

- **Accuracy of representation**: dependent on group membership, not object type

- **Linking representations**: object type does not matter for children without difficulties
  - But it matters for children with difficulties
  - Performance suffers when objects are detachable and countable, or non-detachable and non-countable
Interpretations

D-C objects
→ Not easy to manipulate
Interpretations

**D-C objects**

→ Not easy to manipulate

**ND-DC objects**

→ Does not explicitly reveal the base-10 structure
Interpretations

D-C objects
→ Not easy to manipulate

ND-C objects
→ Easy to manipulate
→ Explicitly reveal the base-10 structure

ND-DC objects
→ Does not explicitly reveal the base-10 structure
Implications

- Physical affordances matter for learning, but their impact differs by level of math difficulty.

- Importance of choosing the appropriate manipulatives for children who struggle:
  - Non-detachable objects for the learning about number and place value.
  - Visibility of place-value concepts.
Future Research Directions

- Younger children without difficulties?
- Which cognitive variables might explain object-type effects?
- Detachability and countability effects after explicit instruction?
- Detachability and countability effects on addition and subtraction?
Thank you!

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