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

Anne Lafay
Helena P. Osana
Olivia Hadjadj

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)

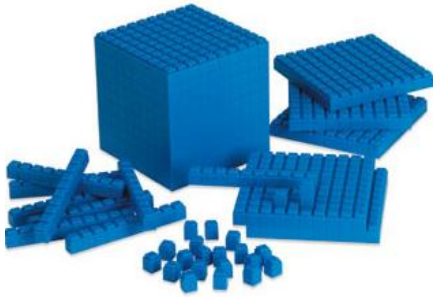
- But not always!

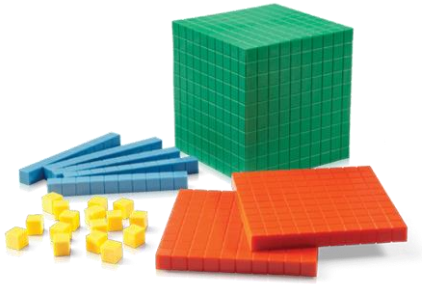
Manipulatives and Mathematics Learning

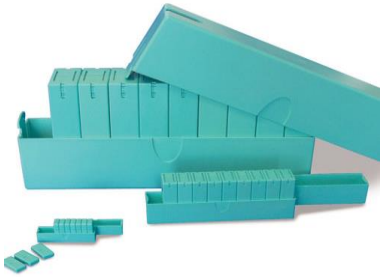
What impacts learning with manipulatives?

- 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)

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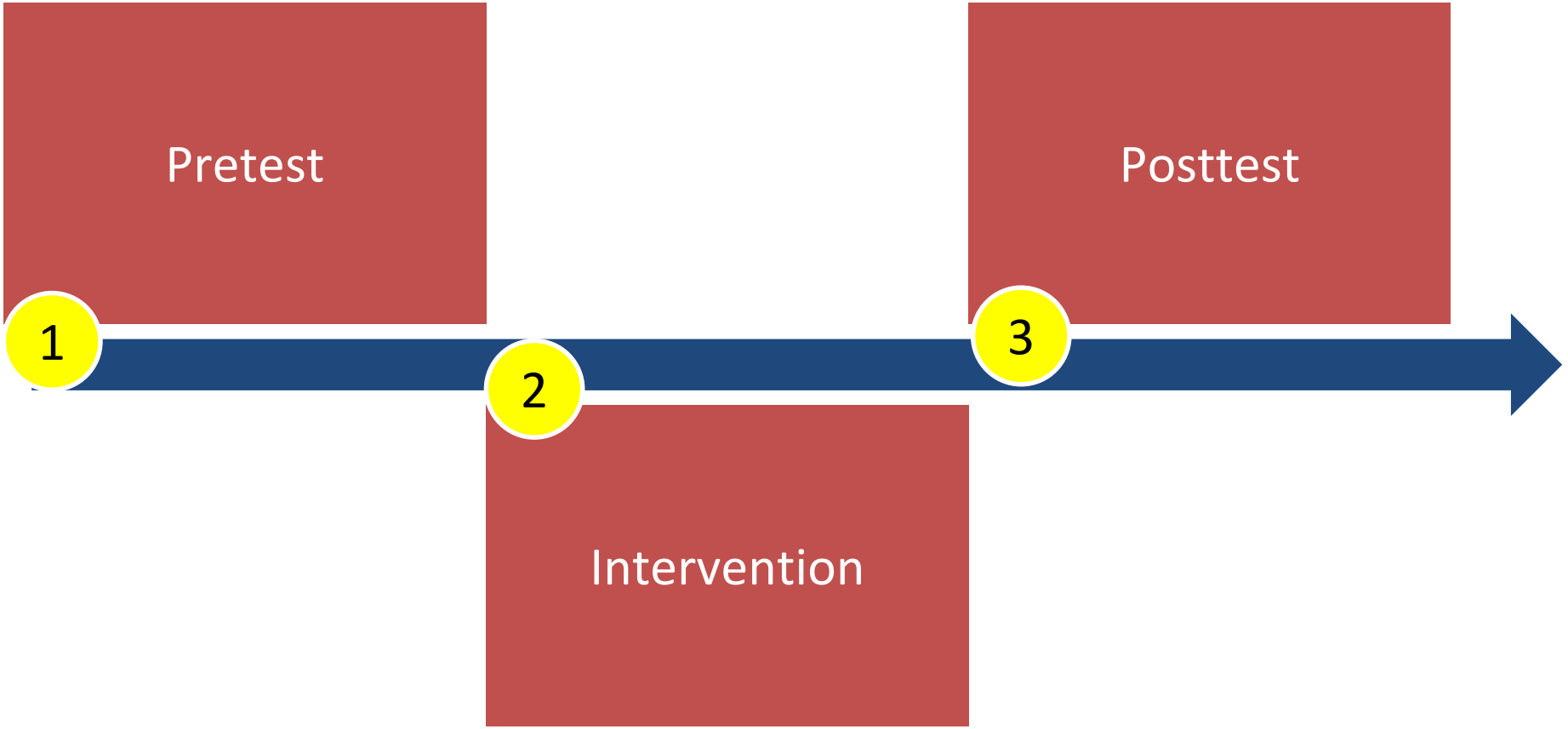
Objectives

- To examine the physical affordances of manipulatives on children's number representation and numeration understanding

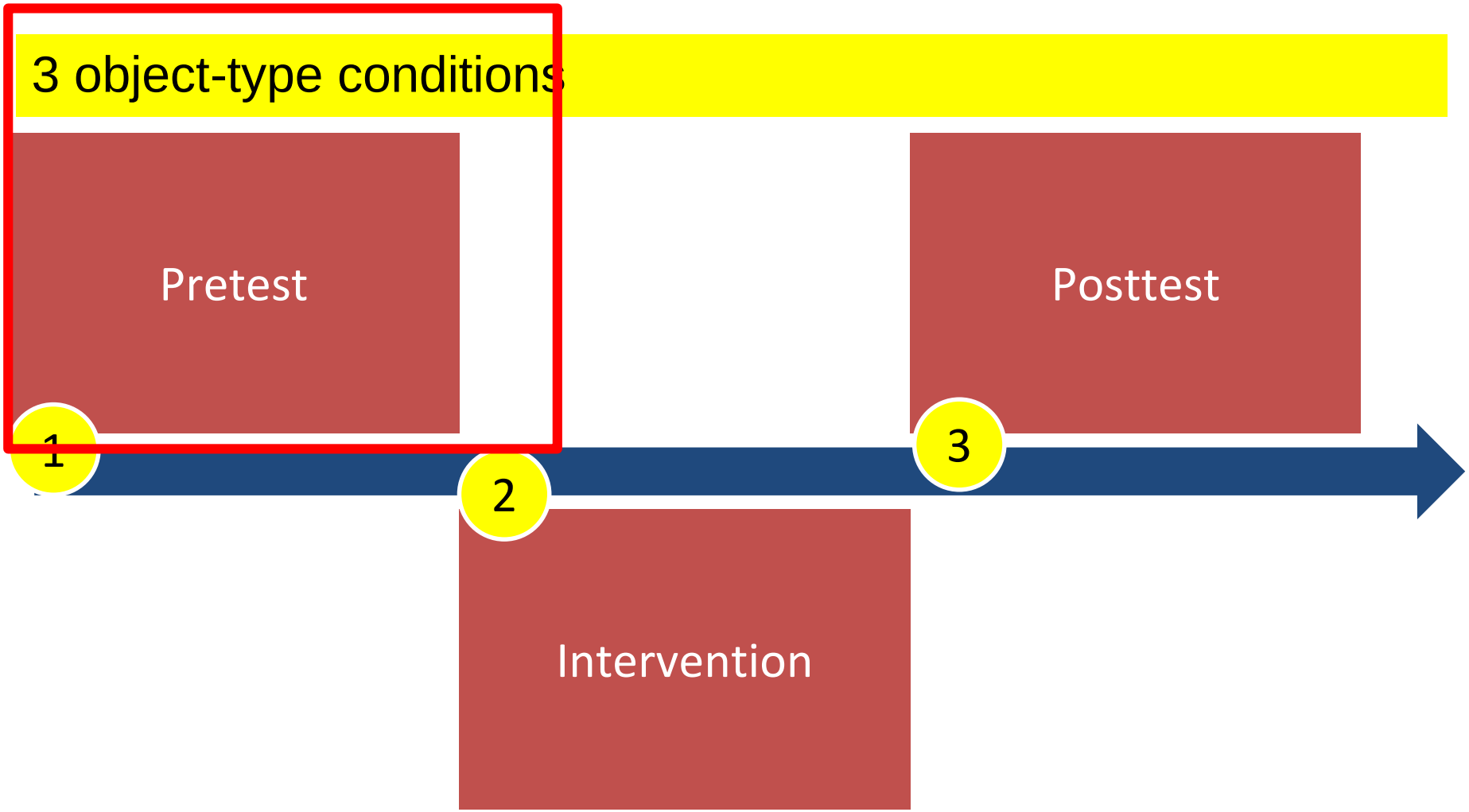
- To compare the impact of physical affordances on two groups of children: with and without mathematics difficulties

Study Design

3 object-type conditions



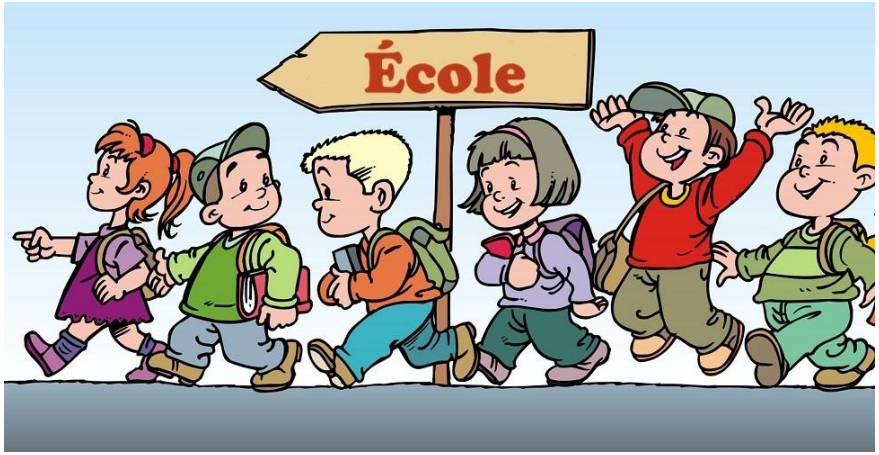
Focus of Present Study



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 > 25th percentile

With mathematics difficulties

N = 29

TTR < 25th percentile

Tempo Test Rekenen (TTR)

Geary, 2013; Lafay et al., 2015

Calcul mental

Nom : _____ Prénom : _____ Classe : _____ Date : _____

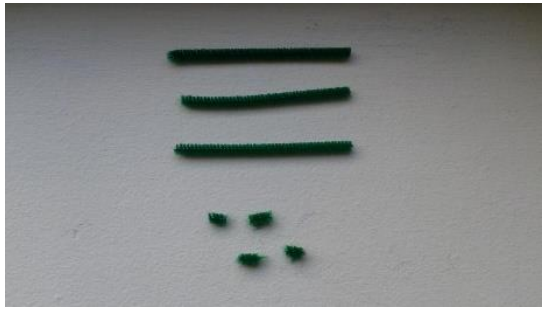
1+1=	3-1=	1x3=	6:2=
2+1=	4-2=	2x2=	4:4=
3+0=	5-2=	1x6=	9:3=
4+1=	2-0=	6x1=	10:5=
2+3=	4-2=	9x0=	16:4=
6+3=	7-3=	2x5=	18:2=
5+4=	8-5=	3x6=	15:3=
7+2=	7-0=	4x4=	24:4=
3+5=	9-2=	5x3=	25:5=
0+8=	9-6=	6x4=	18:3=
7+2=	7-6=	6x8=	33:1=
4+3=	8-4=	8x5=	27:3=
6+4=	6-5=	6x9=	27:9=
5+2=	9-2=	10x5=	33:3=
2+6=	10-5=	9x8=	28:4=
9+2=	14-2=	5x5=	25:5=
9+4=	13-5=	4x7=	64:8=
8+5=	14-6=	8x9=	72:9=
5+9=	17-9=	3x10=	63:9=
6+10=	18-5=	7x7=	70:7=
12+5=	16-4=	9x9=	30:10=
7+11=	17-6=	5x8=	45:9=
8+8=	14-4=	4x9=	44:11=
5+15=	19-8=	11x3=	56:7=
16+4=	18-8=	12x4=	44:4=
7+14=	27-6=	2x15=	38:2=
6+14=	24-8=	26x2=	39:3=
18+6=	26-9=	3x15=	65:5=
17+9=	26-7=	4x25=	42:6=
5+18=	25-9=	6x12=	30:15=
20+30=	35-15=	7x13=	75:25=
19+31=	46-22=	23x4=	80:20=
18+18=	26-18=	33x3=	54:9=
24+16=	47-33=	18x5=	93:3=
29+14=	24-19=	31x4=	100:25=

Object-Type Conditions

Detachable & countable (D-C)

Non-detachable & countable (ND-C)

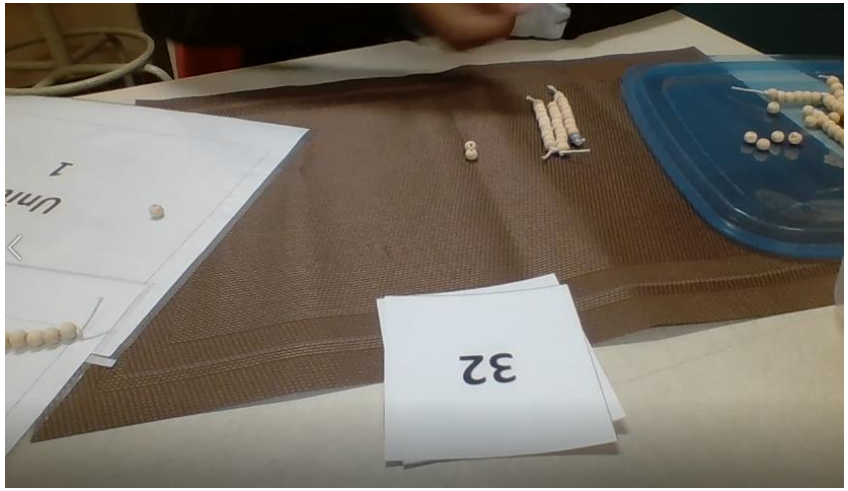
Non-detachable & non-countable (ND-NC)



Measures

1. Representation Task

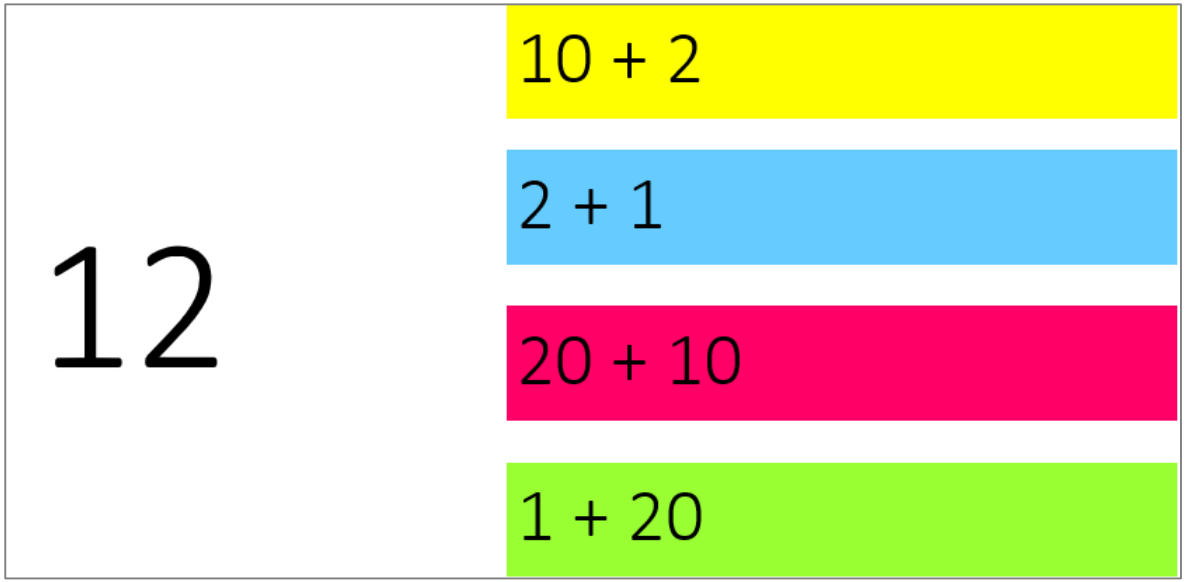
- Representation of numeral with manipulatives
- Four items: Two 2-digit and two 3-digit
- Two scores:
  - (a) Accuracy of representation
  - (b) Linking representations



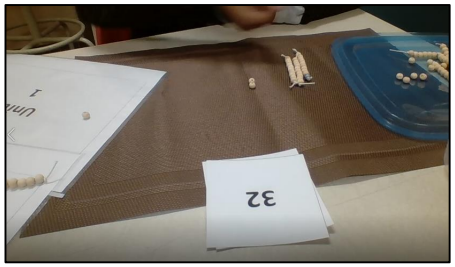
Measures

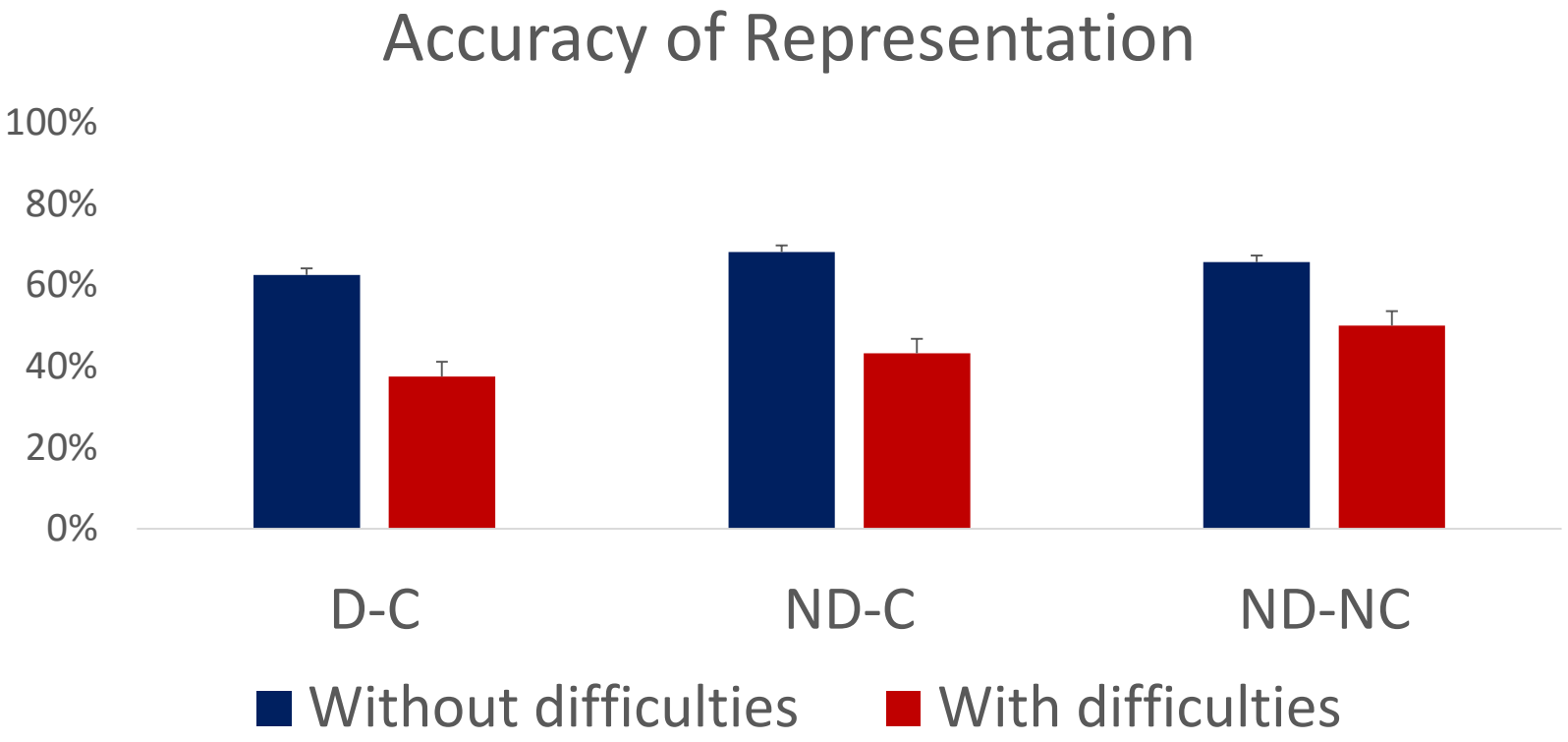
2. Symbolic Decomposition Task

- Symbolic numbers → decomposition
- 20 items: Ten 2-digit numbers and ten 3-digit numbers



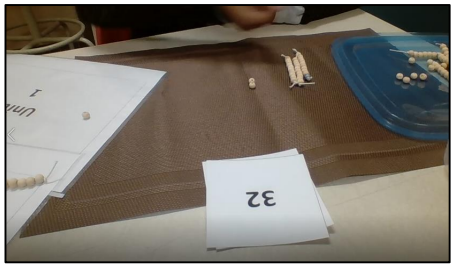
Results

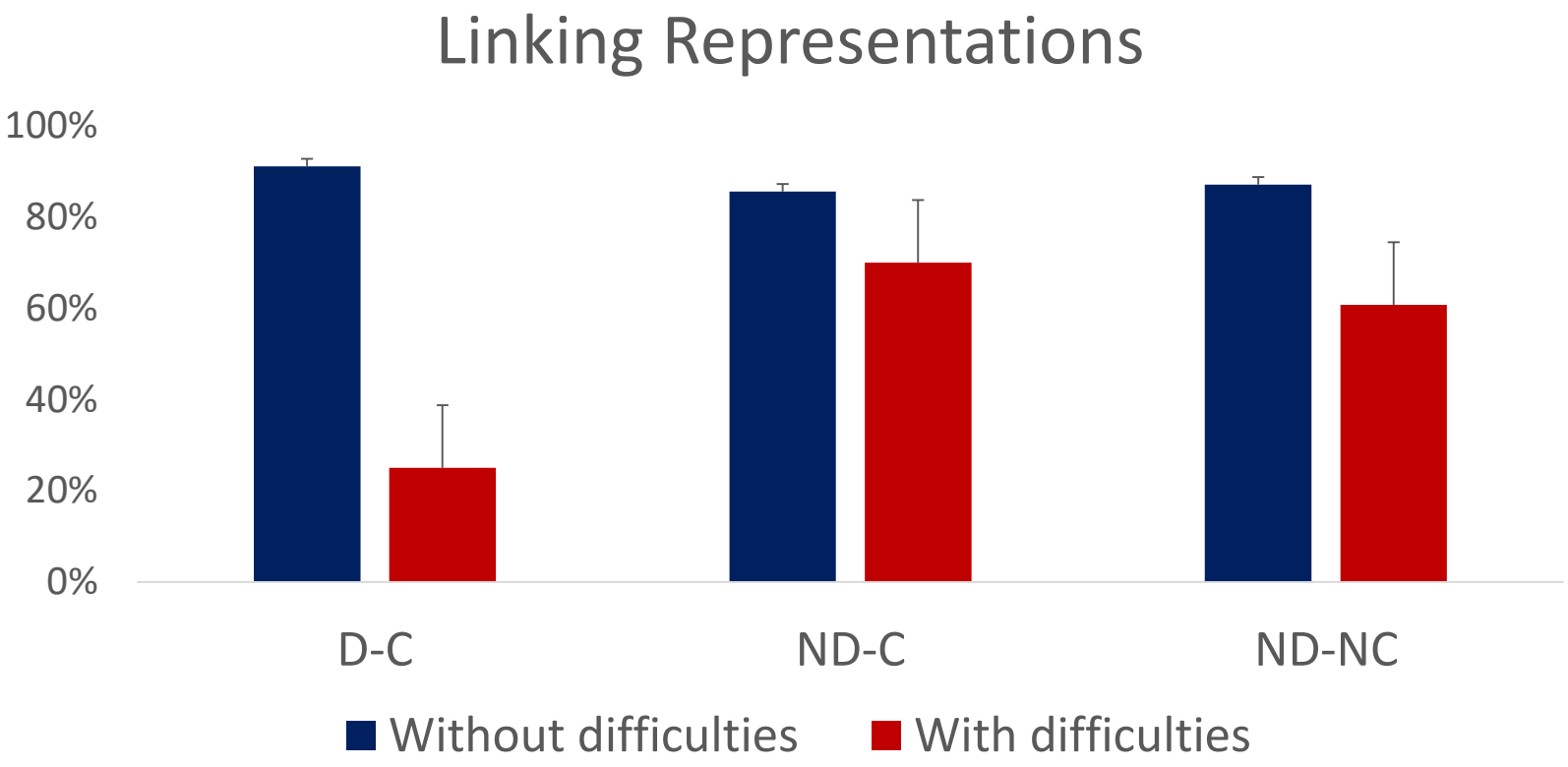




Group: ***p* < .001**
Object Type: *p* = .156
Group x Object Type interaction: *p* = .076

Results

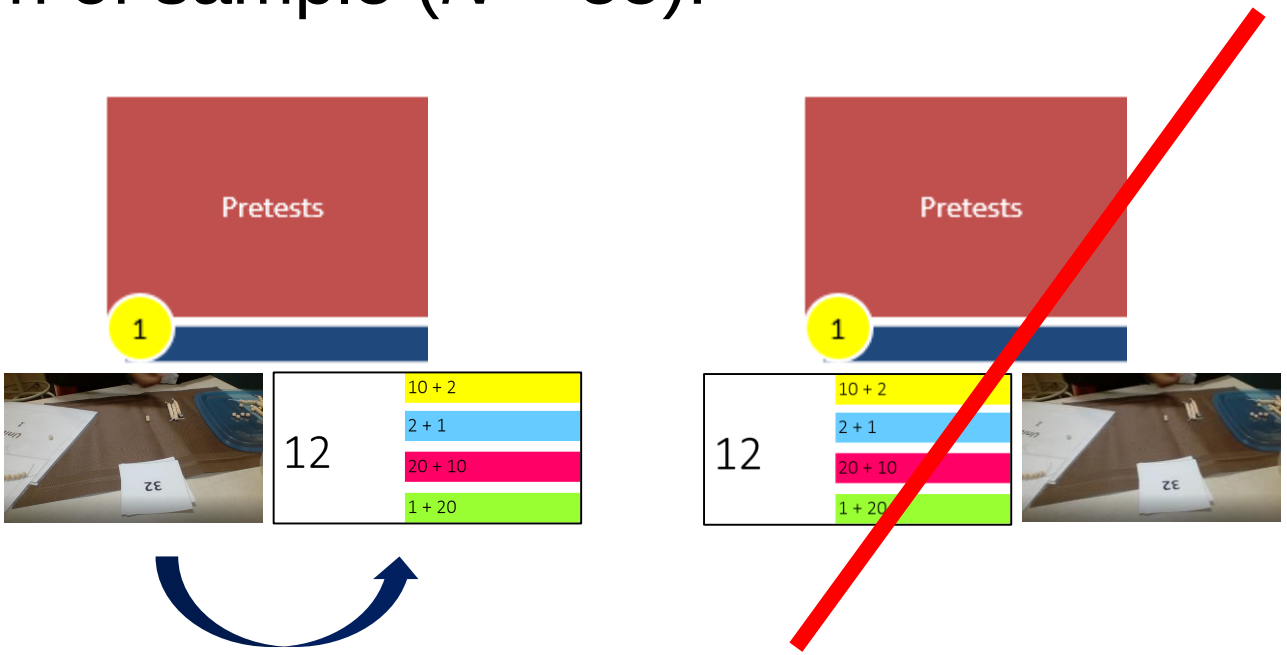




Group: ***p* < .001**
Object Type: *p* = .071
Group x Object Type interaction: ***p* = .016**

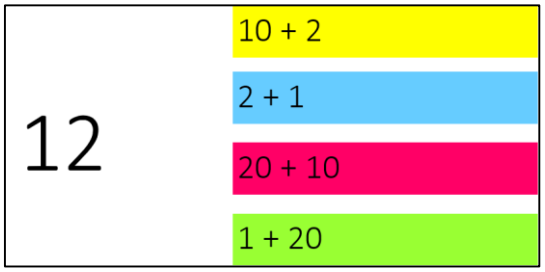
Symbolic Decomposition Task

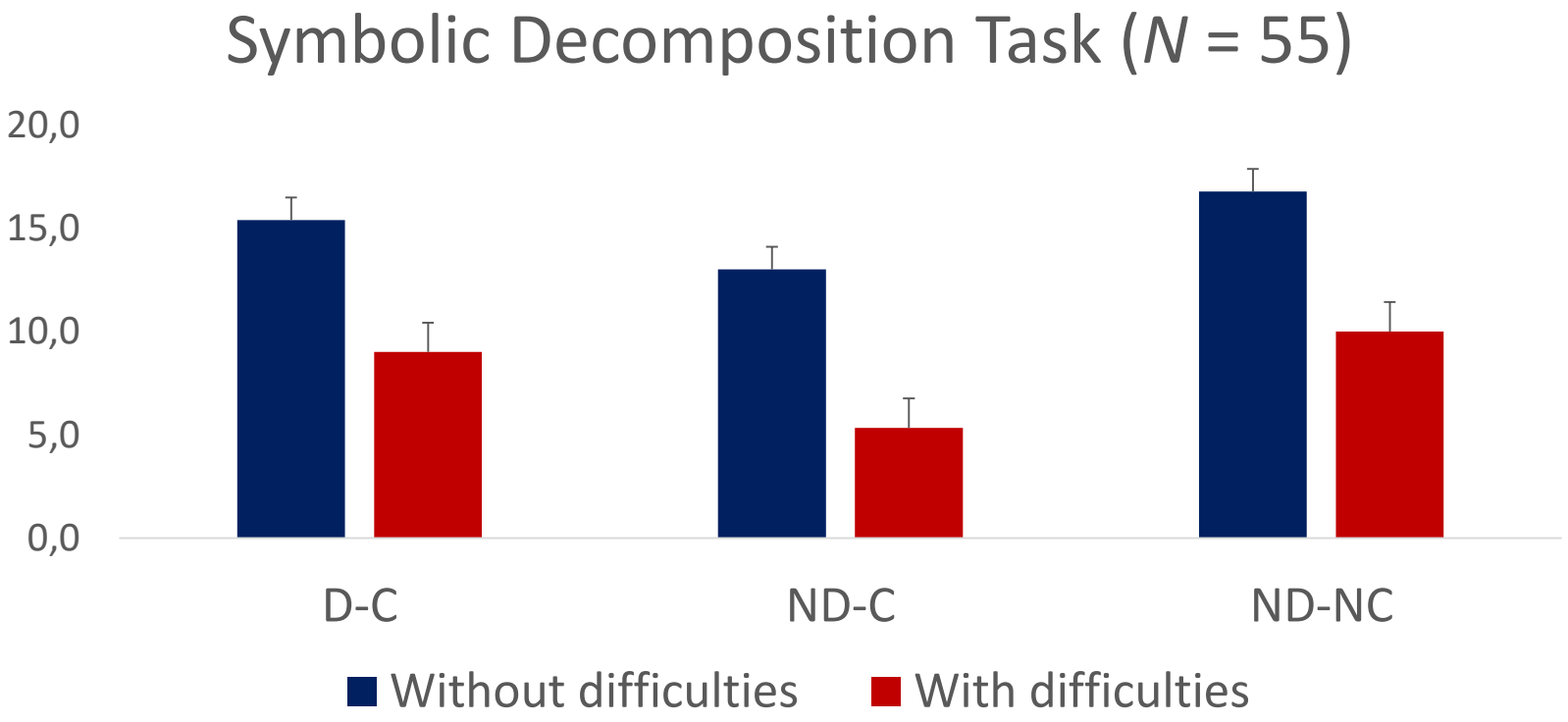
Portion of sample (*N* = 55):



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

Results





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

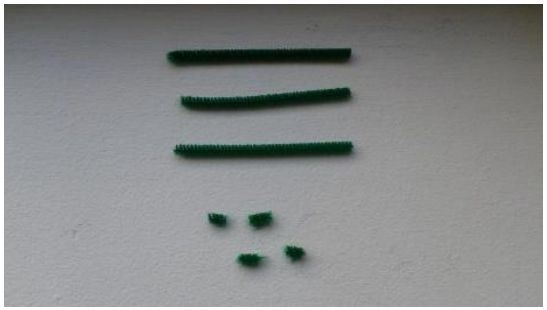
Interpretations

D-C objects

→ Not easy to manipulate

Interpretations

D-C objects
→ Not easy to manipulate

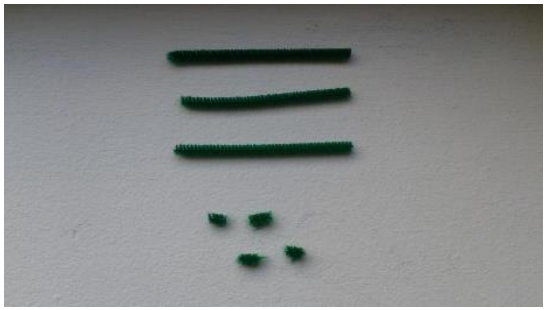


ND-DC objects
→ Does not explicitly reveal the base-10 structure

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!

Arielle Angbole
Gabrielle Lamoureux
Kiera Vaccaro
Marion Valat

Caroline Mura
Julie Robidoux
Marie Brault
Morgane Didier

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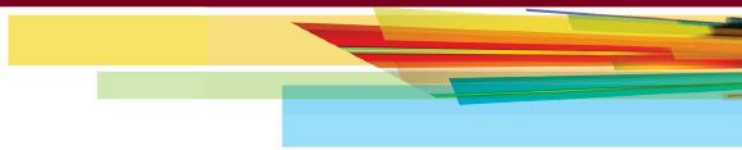
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