

# Learning Math through interactions with peers and with intelligent machines

LÍNEA en COGNICIÓN MATEMÁTICA

CENTRO INTERDISCIPLINARIO EN COGNICIÓN PARA  
LA ENSEÑANZA Y EL APRENDIZAJE (CICEA).  
UNIVERSIDAD DE LA REPÚBLICA



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# Math cognition research group at CICEA



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COGNICIÓN NUMÉRICA

<http://cognicionnumerica.psico.edu.uy>

# Learning Math through interactions with peers and with intelligent machines

(Project funded by the National Research and Innovation Agency in Uruguay)

IPs: Alejandro Maiche (UdelaR) and Elizabeth Spelke (Harvard)

The aim of this project is to study the impact of an intervention in early mathematics through a non-symbolic-symbolic mapping game, presented in different formats:

- a **peer interaction** situation with a concrete game
- a situation of **individual interaction** with a digital game



# PARTICIPANTS

- ◆ 212 participants (128 KG and 84 FG)
- ◆ Age in months = 77 (65-91)
- ◆ From Five Education Centers (all privates).
  - 3 schools of High SES
  - 1 school of Middle SES
  - 1 school of Low SES



# DESIGN of the FIELD EXPERIMENT

PRE

INTERVENTION

POST

**How can we evaluate 212 children of 5 and 6 years in mathematical skills in weeks?**

We developed a math assessment test adapted to Uruguay

## Characteristics:

- ◆ Digital and self-management.
- ◆ 9 sub-tasks.
- ◆ Include symbolic and non-symbolic components.
- ◆ Total duration: 25 min per group

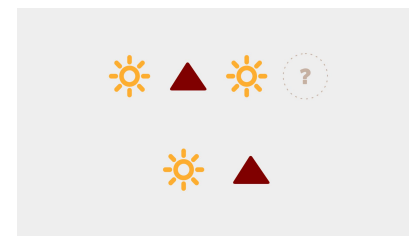
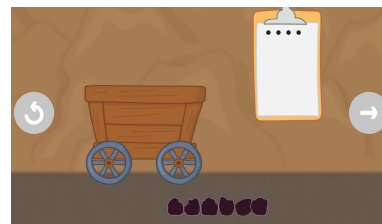
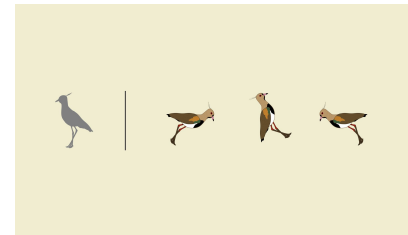
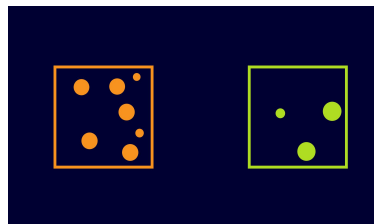
<https://puma.cicea.uy/>



# PUMA: tasks & scores

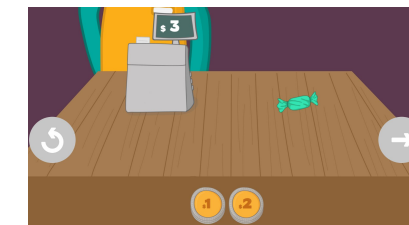
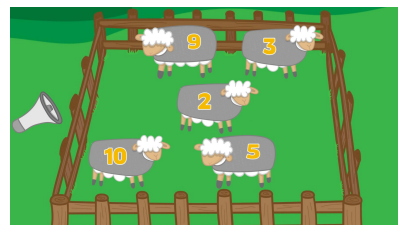
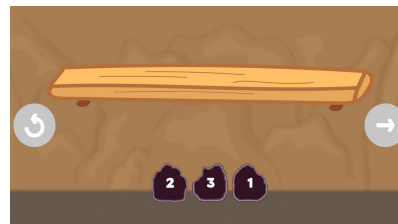
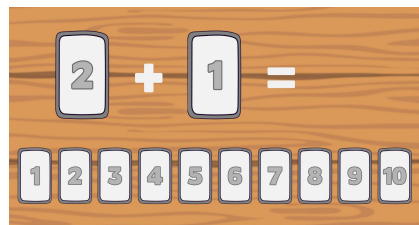
## 4 non-symbolic tasks: 61

1. ANS: 32
2. Mental Rotation: 12
3. Counting: 7
4. Patterns: 10



## 5 symbolic tasks: 95

1. Order Forwd: 10
2. Order Backwd: 10
3. Transcoding: 20
4. Quantity composition: 21
5. Calculation fluency: 34



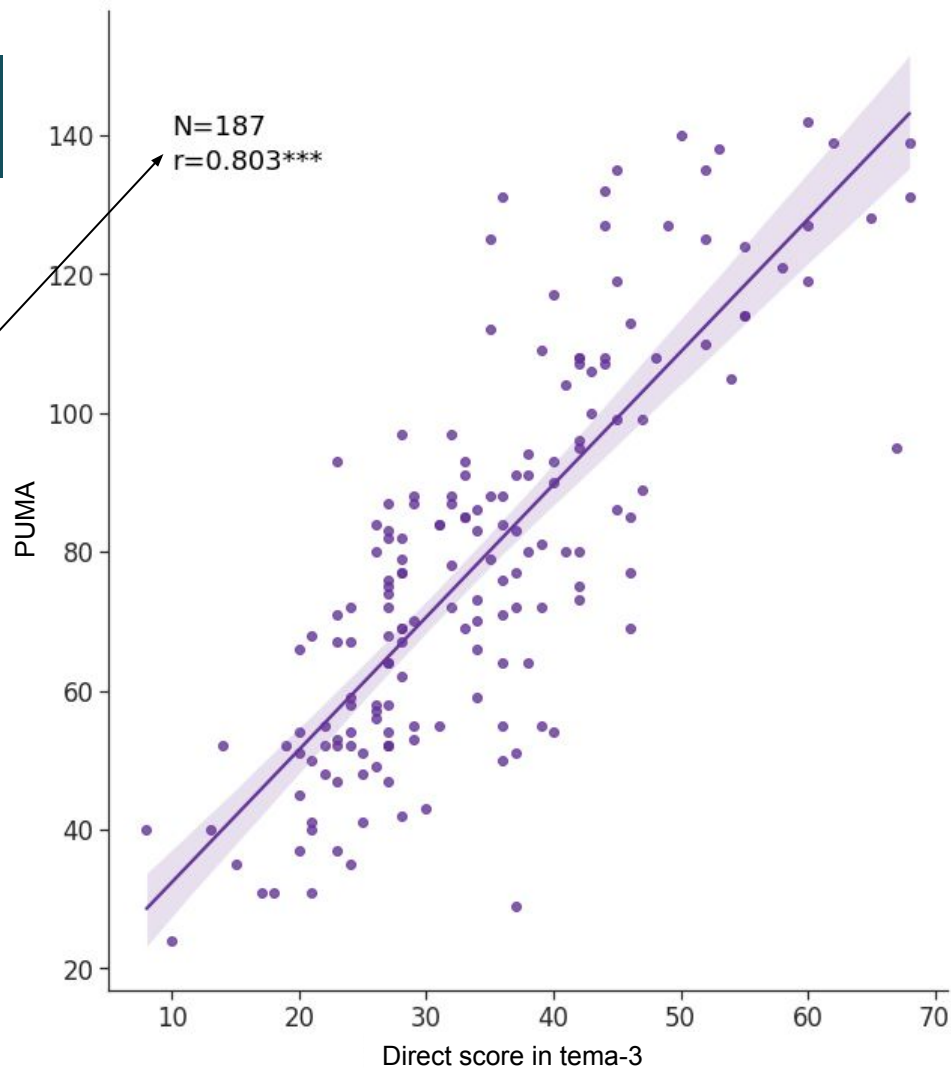
Have a look here: <https://puma.cicea.uy/>

# PUMA

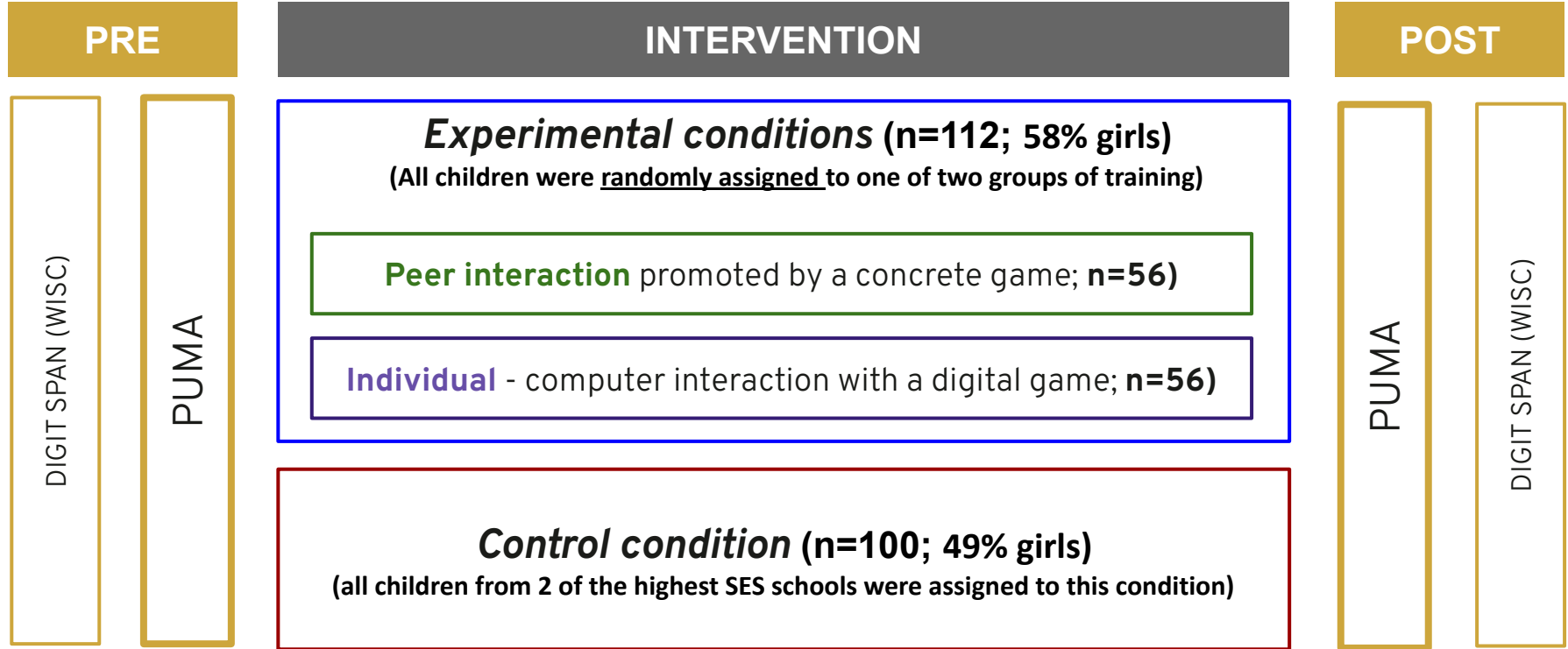
## Correlation with TEMA3

◆ Positive Pearson's correlation  
( $p < 0.01$ ).  $N = 187$

PUMA seems to be a great math  
assessment TEST, at least for KG and G1



# DESIGN of the FIELD EXPERIMENT



# THE GAME

(same game for both experimental conditions)

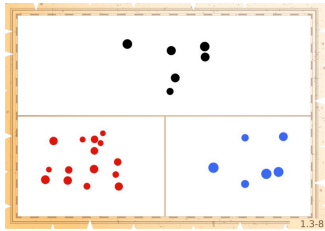
- ◆ The game is embedded in a story about a pirate who left a hidden treasure
- ◆ Children must discover the secret messages left by the pirate. Messages are encrypted in the form of *mathematical tasks* (at the cards).
- ◆ The story and the *mathematical tasks* were identical for each condition but using different support:
  - magic box for the **peer interaction condition**
  - tablet for **individual digital condition**



# THE GAME - *Mathematical tasks*

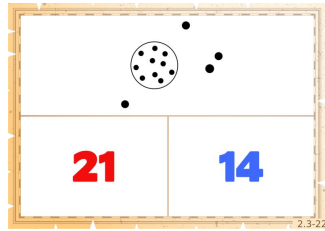
- ◆ A total of 540 cards (5 categories, 15 decks - 3 decks per week)
- ◆ 5 weeks of intervention (3 sessions per week: 1 deck per session)

Week 1



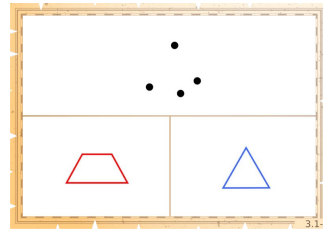
Ratios: 2.23; 2.17; 2.09

Week 2

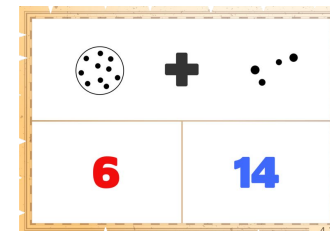


2.04; 1.95; 1.98

Week 3

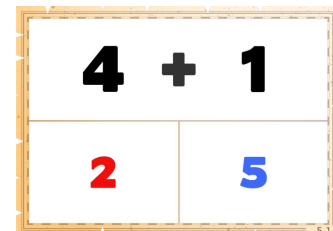


Week 4



1.82; 1.79; 1.77

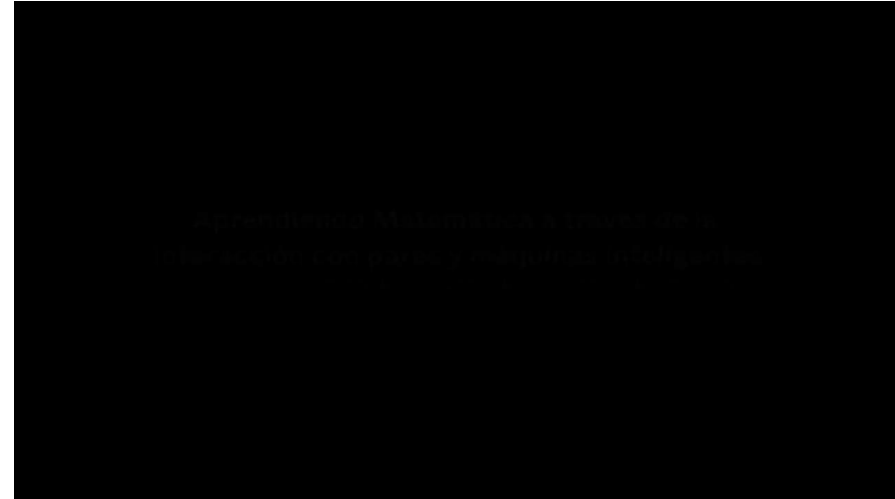
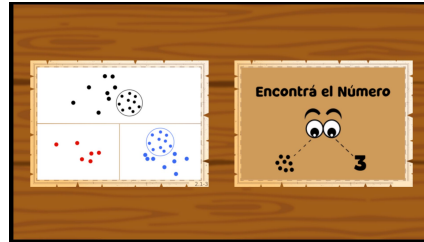
Week 5



1.63; 1.62; 1.59

- ◆ two alternative forced choice
- ◆ counterbalanced response
- ◆ easy to hard

# THE GAME - Individual Digital condition

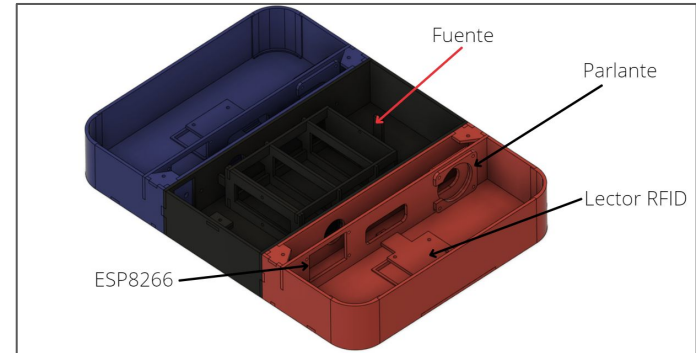
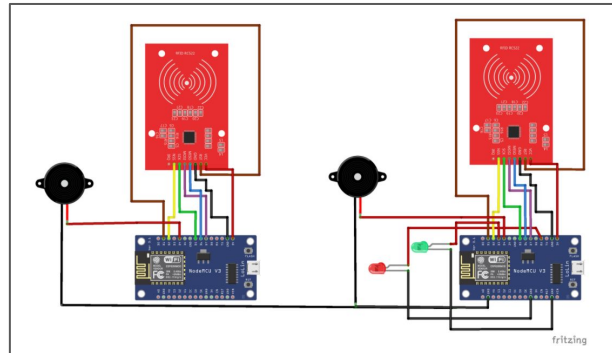


- To Play the game here:  
<http://math.psico.edu.uy/cognum/pirata/1-1.html>

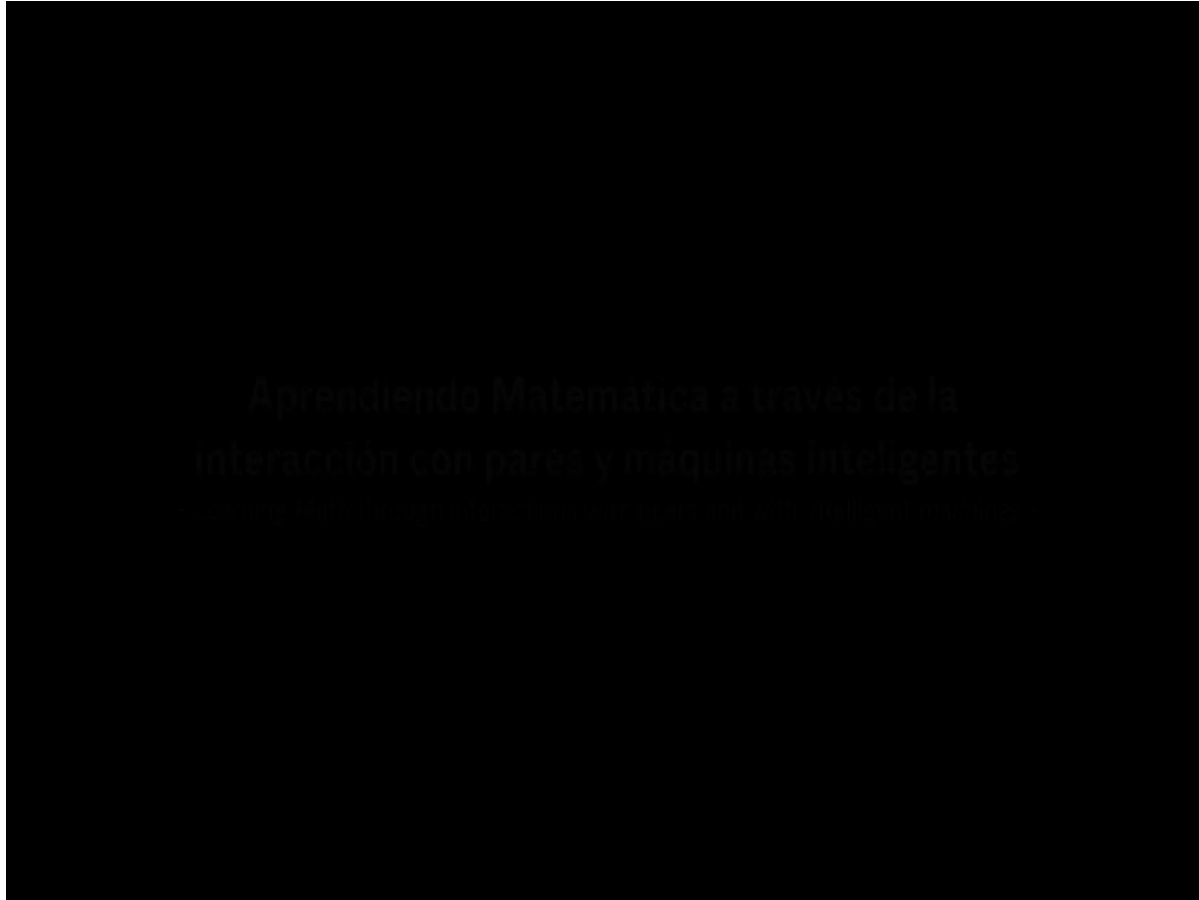
# THE GAME in Peer interaction condition

- ◆ 4 children play for each **magic box**
- ◆ One card is dealt per child
- ◆ The children must choose an answer (red or blue) and pass the card to the side of the box that has that color
- ◆ After every 4 cards, the magic box emits a sound:
  - **Positive sound:** if all four cards were correct
  - **Negative sound:** if at least one card was wrong—: LETS TALK

- 2 NodeMCU ESP8266 (arduinos)
- 2 RFID Readers RC522
- 2 x 40mm 80hm / 0.5W speakers
- 1 Forza battery of 5v output
- 1 USB hub with 4 outputs

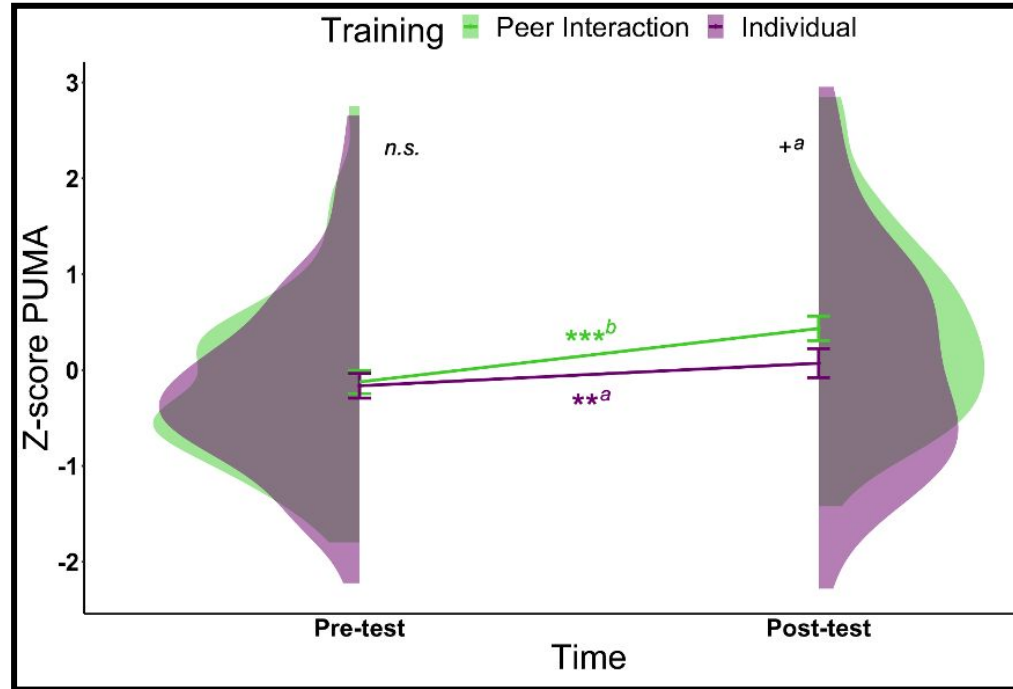
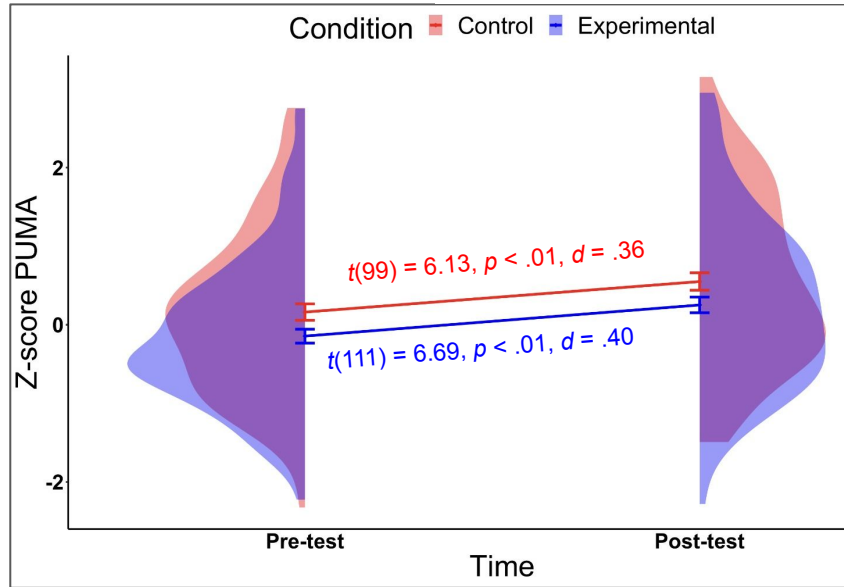


# children playing in **Peer interaction** condition



Aprendiendo Matemática a través de la  
interacción con pares y máquinas inteligentes  
en un entorno de aprendizaje personalizado y adaptativo

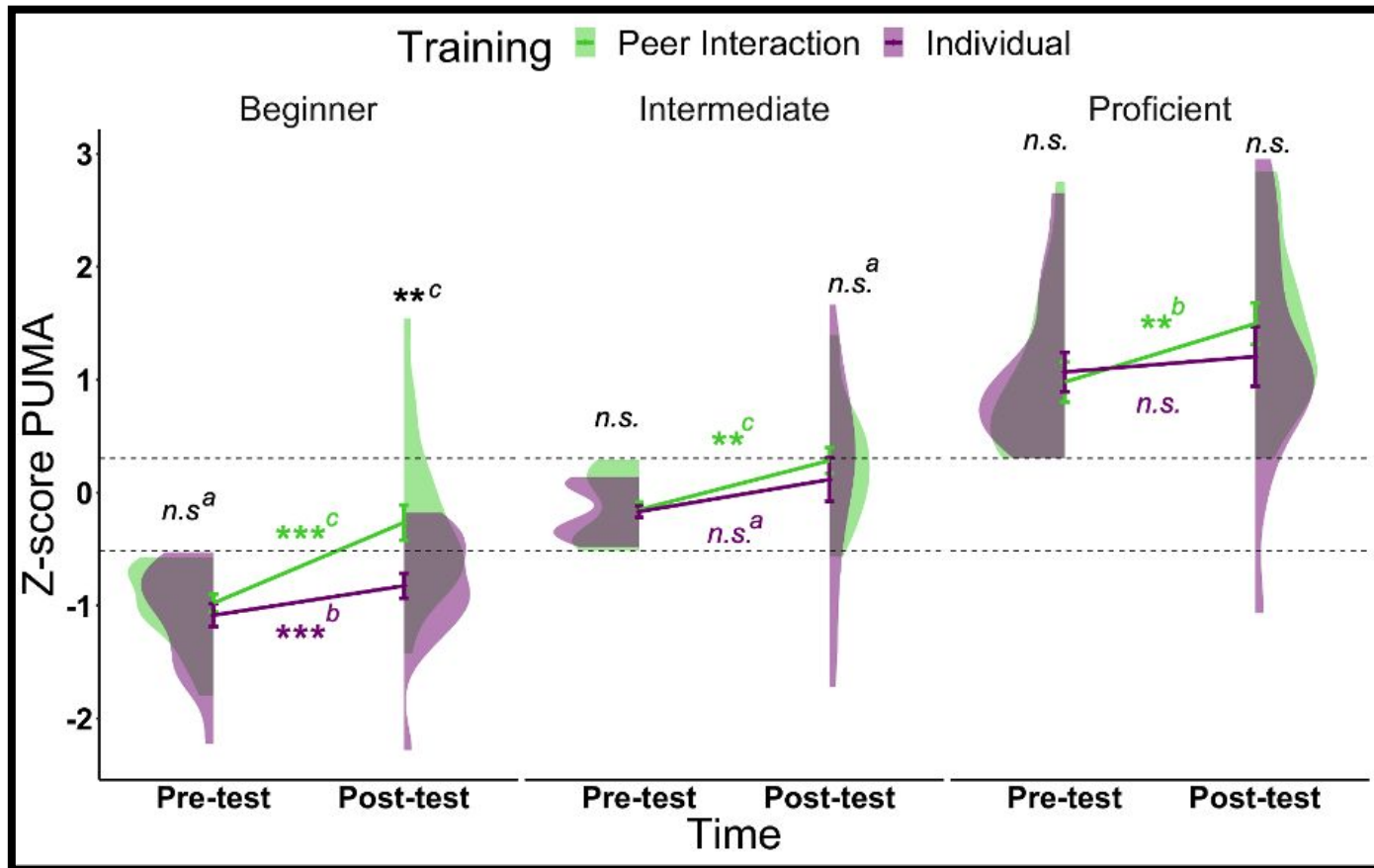
# RESULTS:



# RESULTS:

To analyze the effect of the intervention across different ability levels of mathematical performance, **we performed a *post-hoc* analysis dividing the whole sample into three groups:**

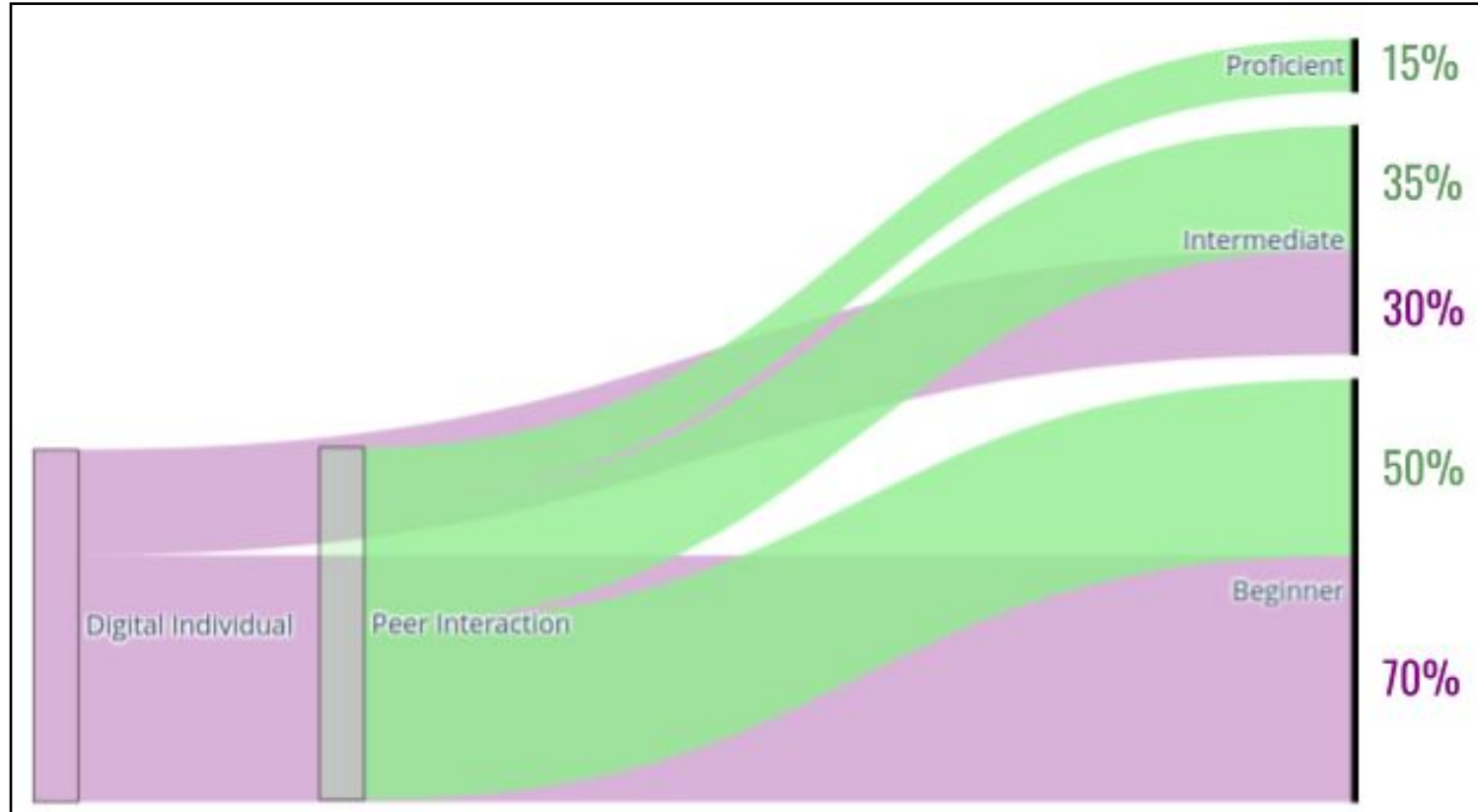
*Beginner* (first tercile in the standardized measure in PUMA in the pre-training assessment),  
*Intermediate* (second tercile) and  
*Proficient* (third tercile).



# RESULTS: Cognitive mobility for beginners

The effect of the training condition is also reflected in the "cognitive mobility" of participants.

In the figure we show the changes of math skills level that our intervention provokes for children who were part of the lowest group (beginners) before the intervention



# Final insight

- Our findings support the idea that training with games in the mapping process between symbolic and non-symbolic information is a key to learning math at an early age
- Peer interaction (promoted through magic boxes) seems to be much more effective than individual play on tablets in cognitively stimulating early mathematical skills for all children, especially in those children whose performance of mathematics is at the lowest level.
- These games implemented in magic boxes that raises the possibility that children have to talk in order to answer correctly as a group seem to be a very powerful mean to for early math learning and could be implemented by the educational system.

# ¡Thanks!

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