Does the development of digital skills influence the development of basic numerical skills in children from three to four years old ?

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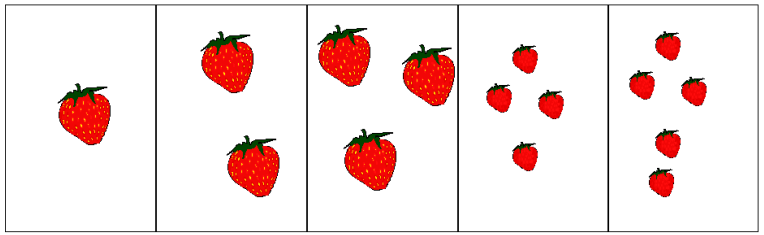
Numerical development

Between the age of 2 and the age of 8, children learn to recite number words

According to Wynn (1992), acquiring the meaning of number words is a long-lasting process :

- Children are able to count until numbers that they are not yet able to understand.
- It's a long and difficult process because the language does not keep track of the increase of quantities.
- This process takes about one year and a half.

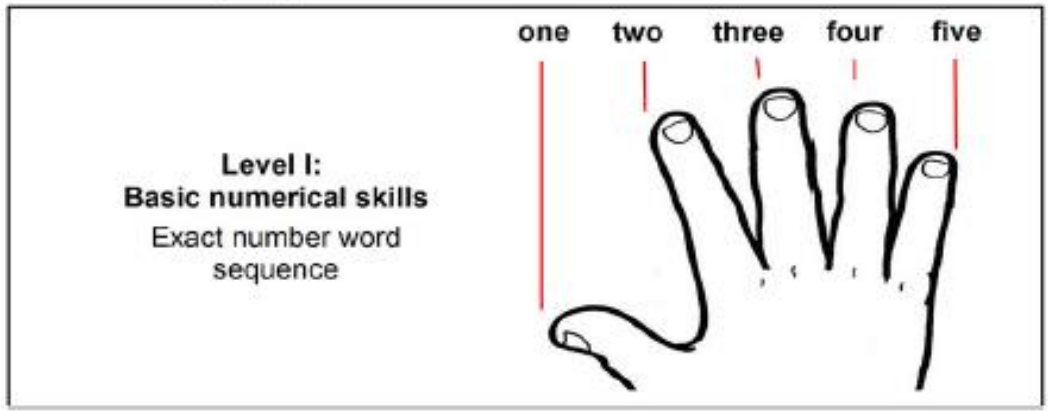
Cardinality



- The learning of cardinal meaning of number words is long and works through different stages (Wynn, 1990, 1992)
  - The first four number words are mastered in order one at a time (Carey, 2009; Sarnecka & Lee, 2009)
    - Children are first « one-knowers », then « two-knowers », « three-knowers » and « four-knowers)
  - Then, children learn that the last number word reached when counting a set represents the size of this set (Gelman & Gallistel, 1978)
    - Children become « Cardinal-Principle » knowers
- This learning takes one year and starts at around the age of 3 years

Fingers and Numbers

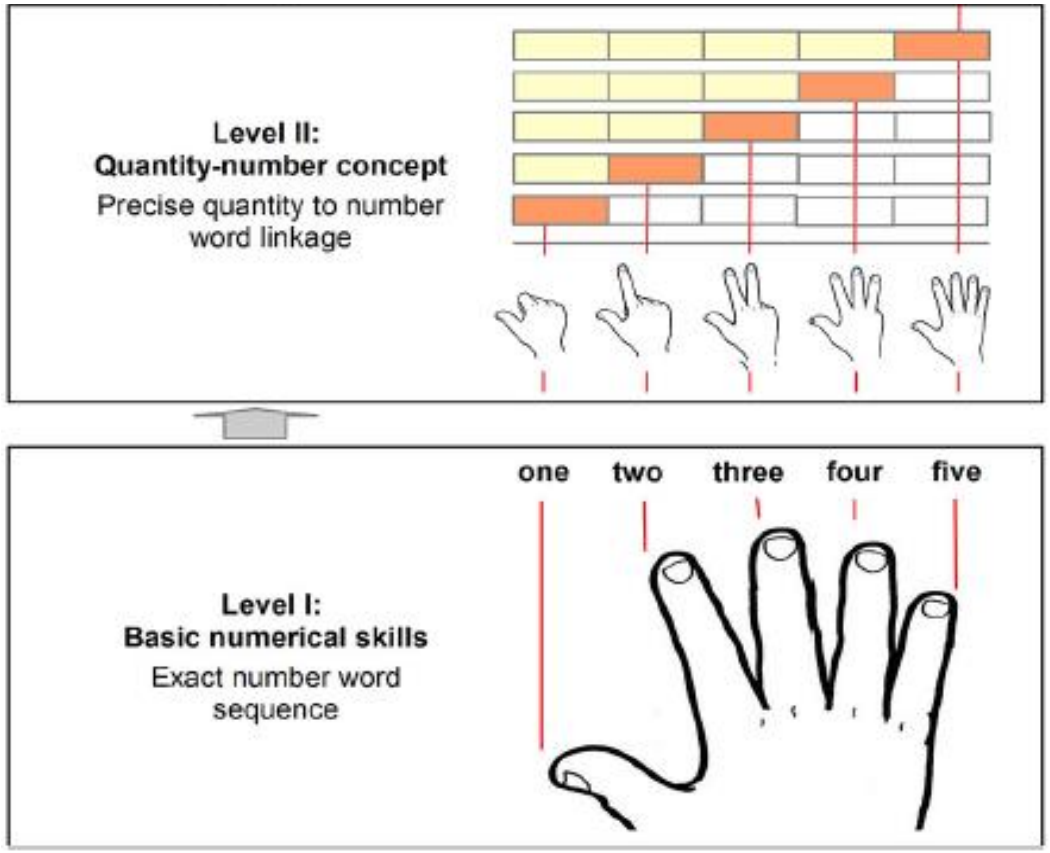
- Functional role played by fingers in numerical development.
  - Individuate number words in verbal number sequence
  - Pointing
  - Counting on fingers in one-to-one correspondence
    - Stable order
    - Iconique cardinal representation
    - Necessary when learning to calculate



Roesch & Moeller (2015)

Association 1 finger-1 verbal numeral

Sustain the acquisition of the verbal number sequence and of the counting procedure (individuation of verbal nb, stable order, tagging, 1-1 correspondence)



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Iconic cardinal representation
Support the association between quantities (digit configuration and verbal number (cardinal principle)

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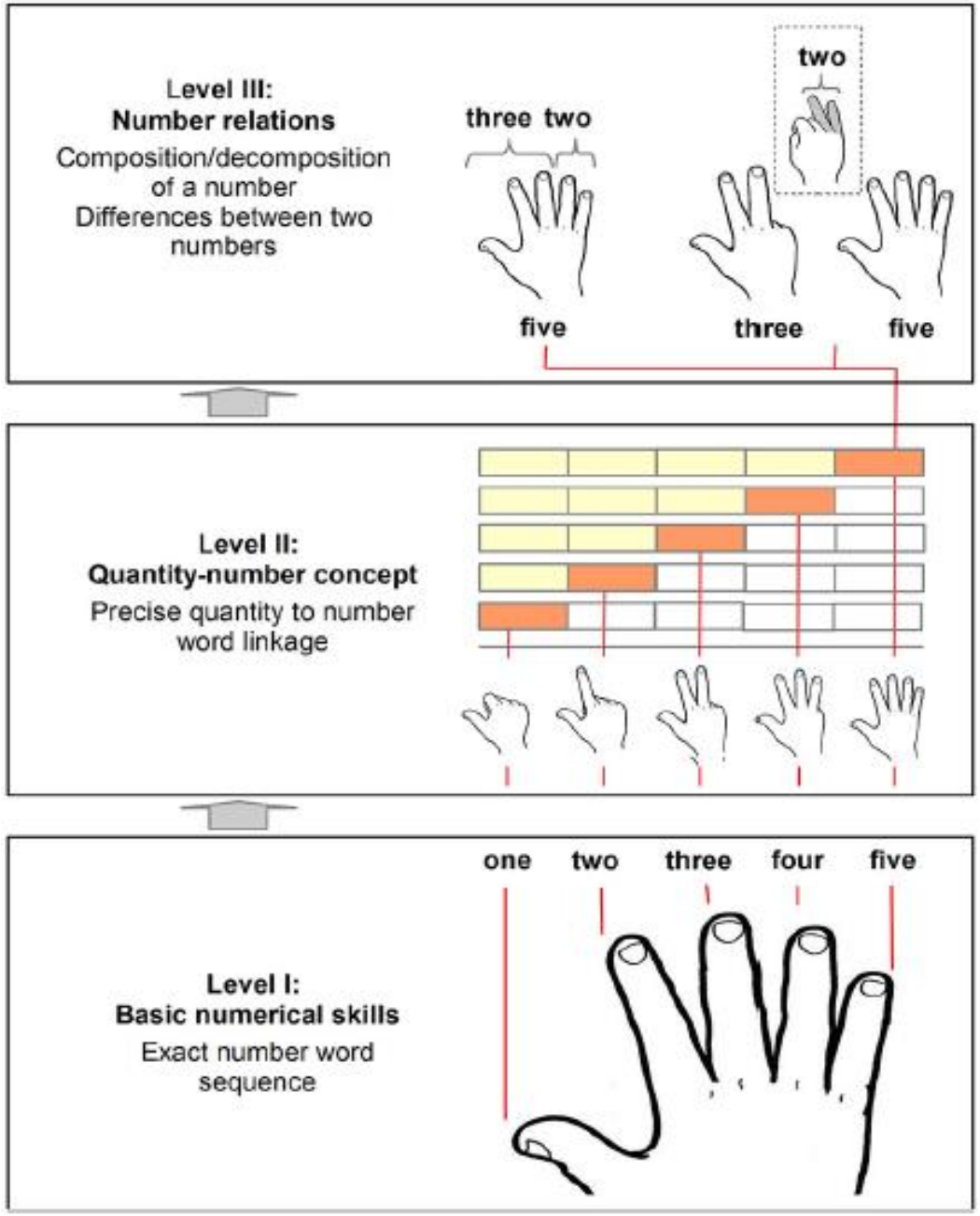

Roesch & Moeller (2015)

A basis for calculation
Decomposition, recomposition andcomparison

Iconic cardinal representation
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Fingers

- Many studies about fingers in counting
  - Fingers are used to keep a visual track in the recitation of the verbal numerical chain (Fuson, Richards & Briars, 1982; Saxe & Kaplan, 1981; Alibali & Di Russo, 1999)

- Many studies about fingers in arithmetic
  - Fingers are usually used by young children to resolve arithmetic tasks (Fuson, 1982)
  - Finger gnosia = good predictor of performance in arithmetic and problem solving (Fayol, Barrouillet & Marinthe, 1998; Noël, 2005)
  - High rate of « split-five » errors (Domahs et al., 2008; : Klein et al., 2011)
  - Interference of hand movement in arithmetical (Crollen & Noël, 2015; Imbo et al., 2011; Michaux et al., 2013)

- BUT… Fingers in the understanding of the cardinality concept are less studied in children.

Cardinal number gestures

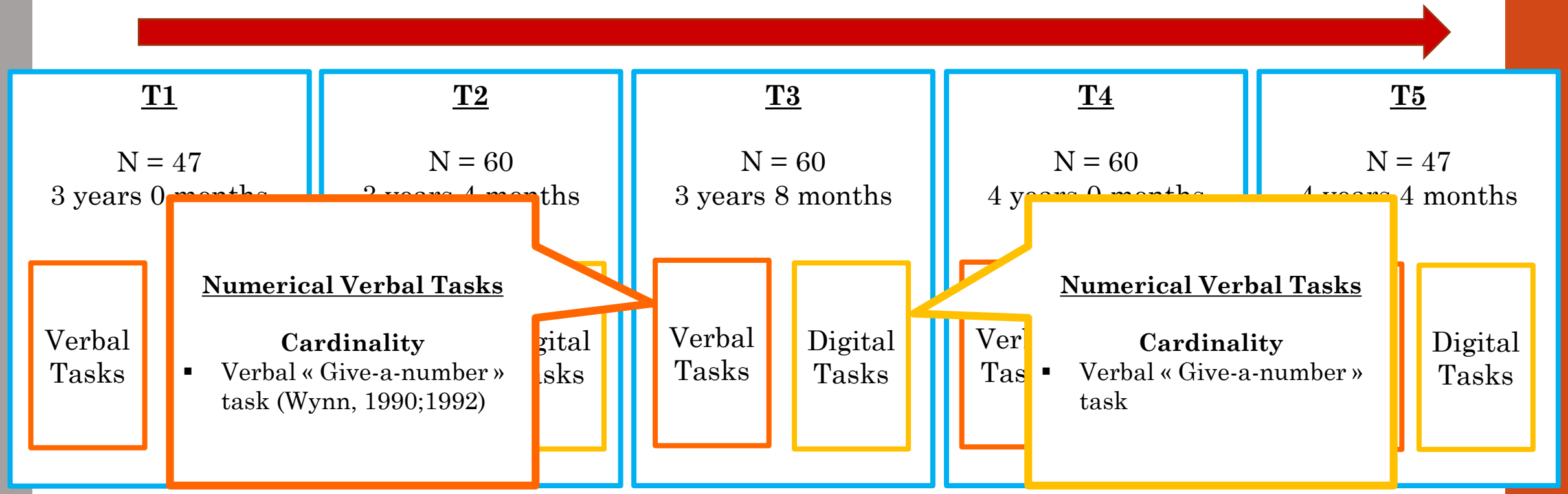
Nicoladis, Pika & Marentette (2010)	Gunderson, Speapen, Gibson & Goldin-Meadow (2015)
Population : 44 children – Groups based on the age (2- to 5-years old) Tasks : *How many* & *Give-a-number* **Conclusion : Children are more accurate with number words than number gestures in both tasks**	Population : 155 children – Groups based on knowledge-level (assessed in *Give-a-number* task) Tasks: *What's on this Card-Gesture* & *What's on this Card-Speech* **Conclusion : Children who are not yet CP-knowers are more accurate labbeling small sets/estimating large sets with gestures than with words**
Limits : • Not an universal advantage for number words through the groups of age	Limits : • Digital training before the tasks could influence the results

No longitudinal study assessing developmental trajectories

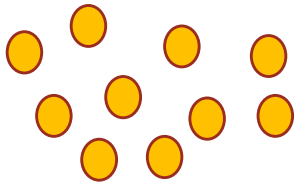
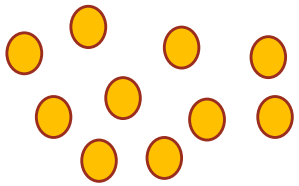
Do the digital skills have any impact on the understanding of the cardinal meaning of number words between the age of three and four years old?

1. Is the understanding of the cardinal meaning of number gestures easier than the understanding of the cardinal meaning of number words at some points of the development ?
2. Does the progress in the understanding of the cardinal meaning of number gestures contribute to the progress in the understanding of the cardinal meaning of number words ?

Experiment design



Tasks assessing Cardinality understanding

Verbal Tasks	Digital Tasks
*« Can you give me **/THREE/** tokens? »* 	*« Can you give me*  *tokens ? »* 

• *Cardinal development level = the largest numerosity accurately identified by the child two out of three times*
  • *5 levels : 5 knowers groups*
  • *1-knowers group*
  • *2-knowers group*
  • *3-knowers group*
  • *4-knowers group*
  • *CP-knowers group*
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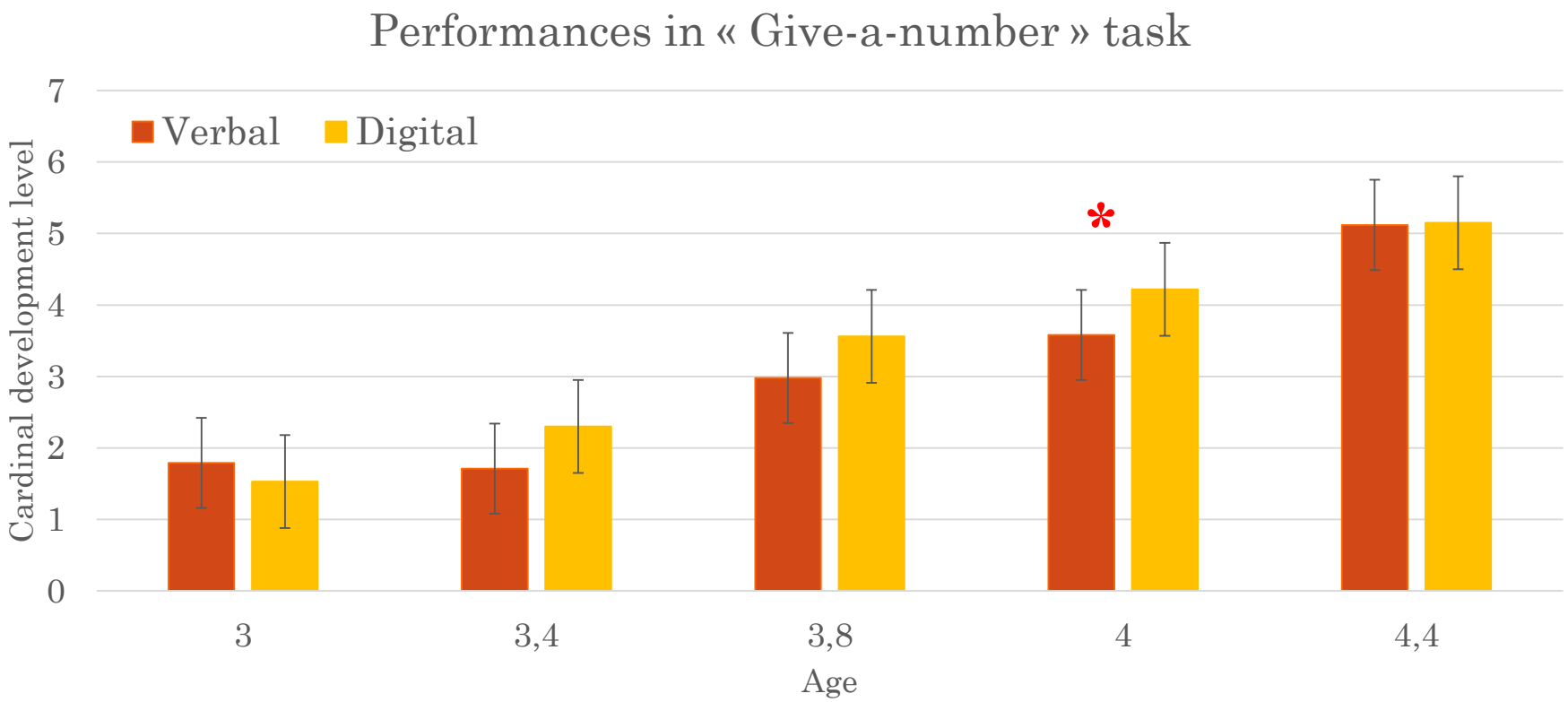

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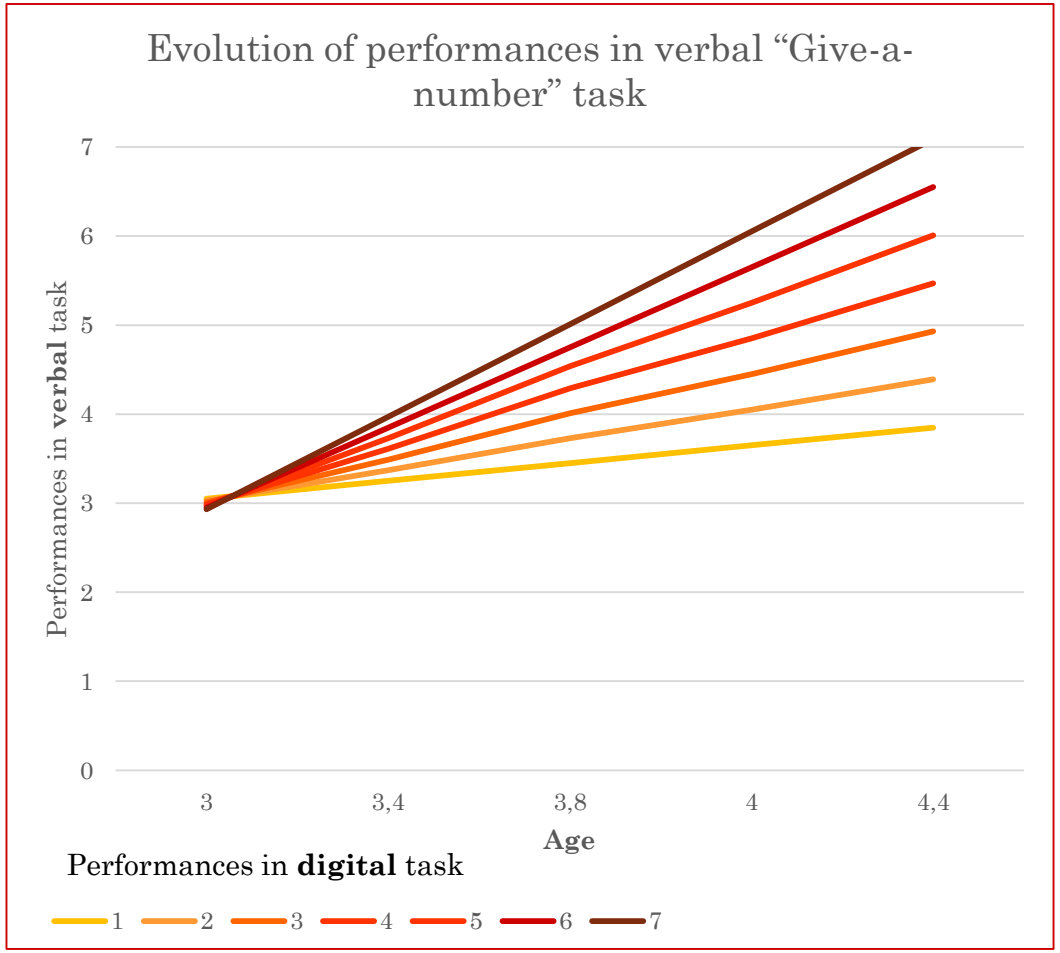
Tasks assessing Cardinality understanding

« Give-a-number » tasks in digital and verbal modalities



Significant effect of interaction between age and digital performance

Tasks assessing Cardinality understanding

In « Give-a-number » task

- Digital cardinal level plays a role in the acquisition of verbal cardinal level, and this impact changes over time.

- The older the children are, the more verbal cardinal level is impacted by digital performance in the same task.

Fingers

- Digital gnosia were described as a good predictor of numeric and arithmetic performance (Fayol, Barrouillet, & Marinthe, 1998; Marinthe, Fayol, & Barrouillet, 2001; Noël, 2005).

- Significant correlations were observed between manual dexterity and performance in addition tasks (Asakawa & Sugimura, 2009, 2011, 2014).
  - Lauzon (1990) split digital dexterity into 2 components : dissociation and coordination.

Gnosia

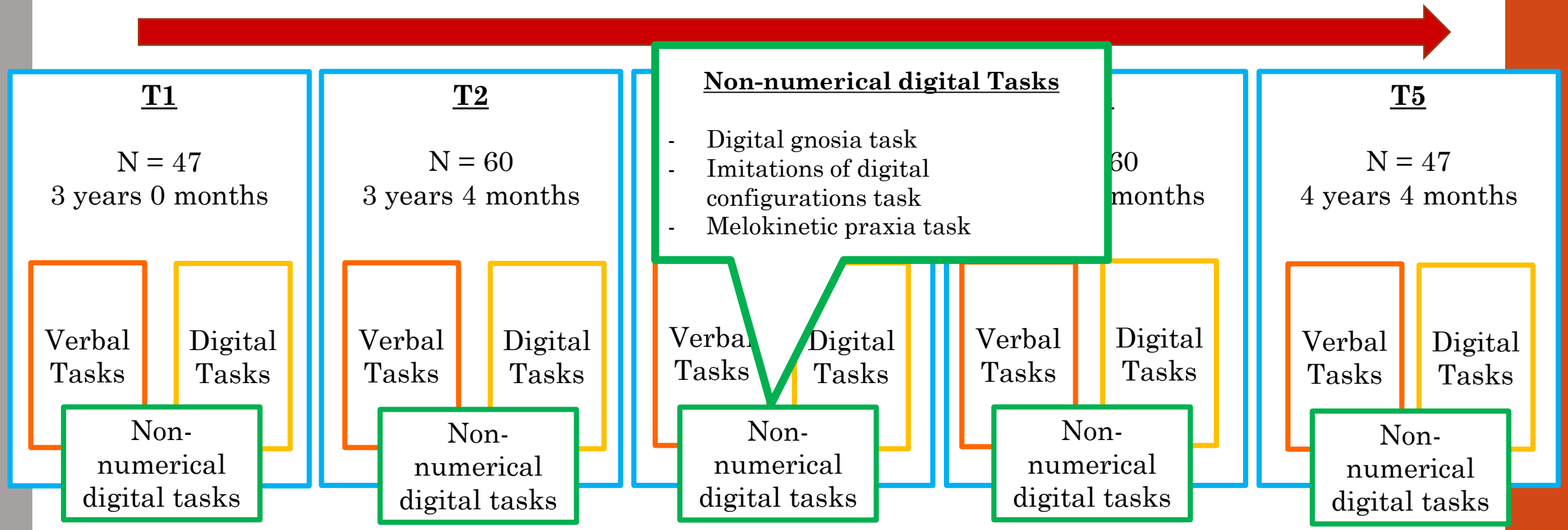
Dissociation

Coordination

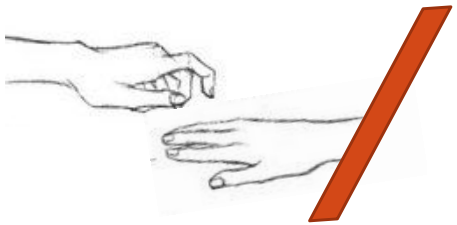
Do the digital skills have any impact on the understanding of the cardinal meaning of number words between the age of three and four years old?

1.
2.
3. Does the development of the digital non-numerical skills contribute to the progress in the understanding of the cardinal meaning of number words ?

Experiment design

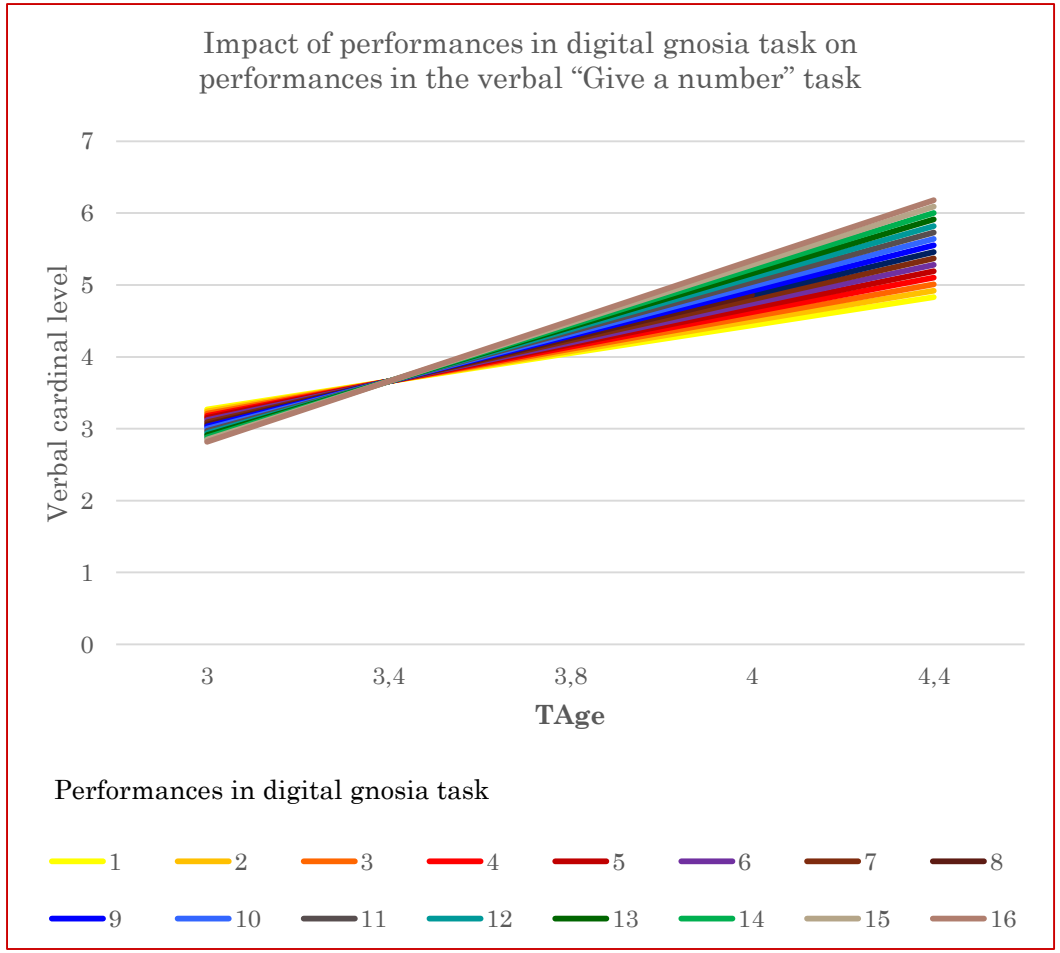


Tasks assessing digital non-numerical skills

Digital gnosia task	Imitation of digital configuration task	Melokinetic praxia task
« Can you say me which finger is touched ? » *8 touched fingers for each hand behind a screen* 	*« Can you do the same than my fingers ? »* 10 digital configurations to imitate for each hand Presentation in mirror 	*« Can you do the same than my fingers ? »* *3 praxia to reproduct for each hand* 

Impact of digital non-numerical skills

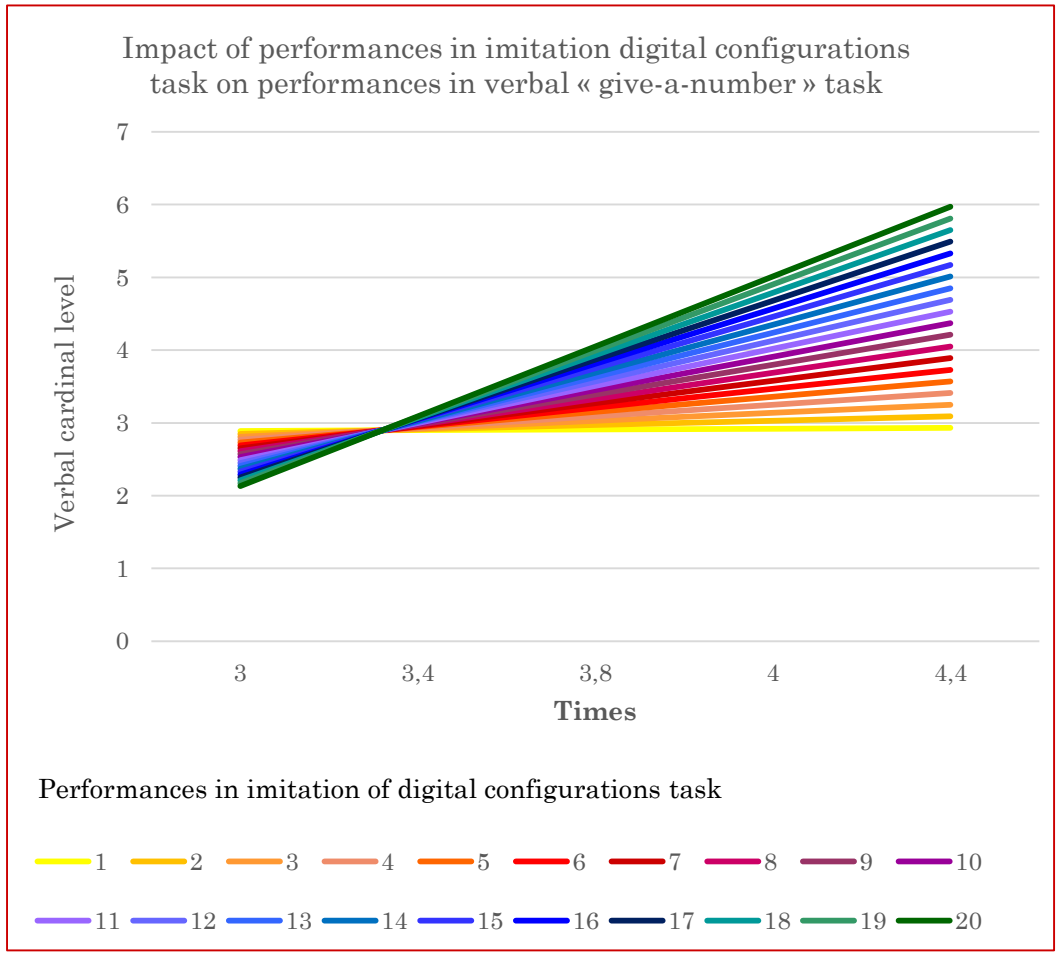
Impact of **digital gnosia performances** on numerical verbal performances



No significant effect of digital performance or interaction

Impact of digitanon-numerical l skills

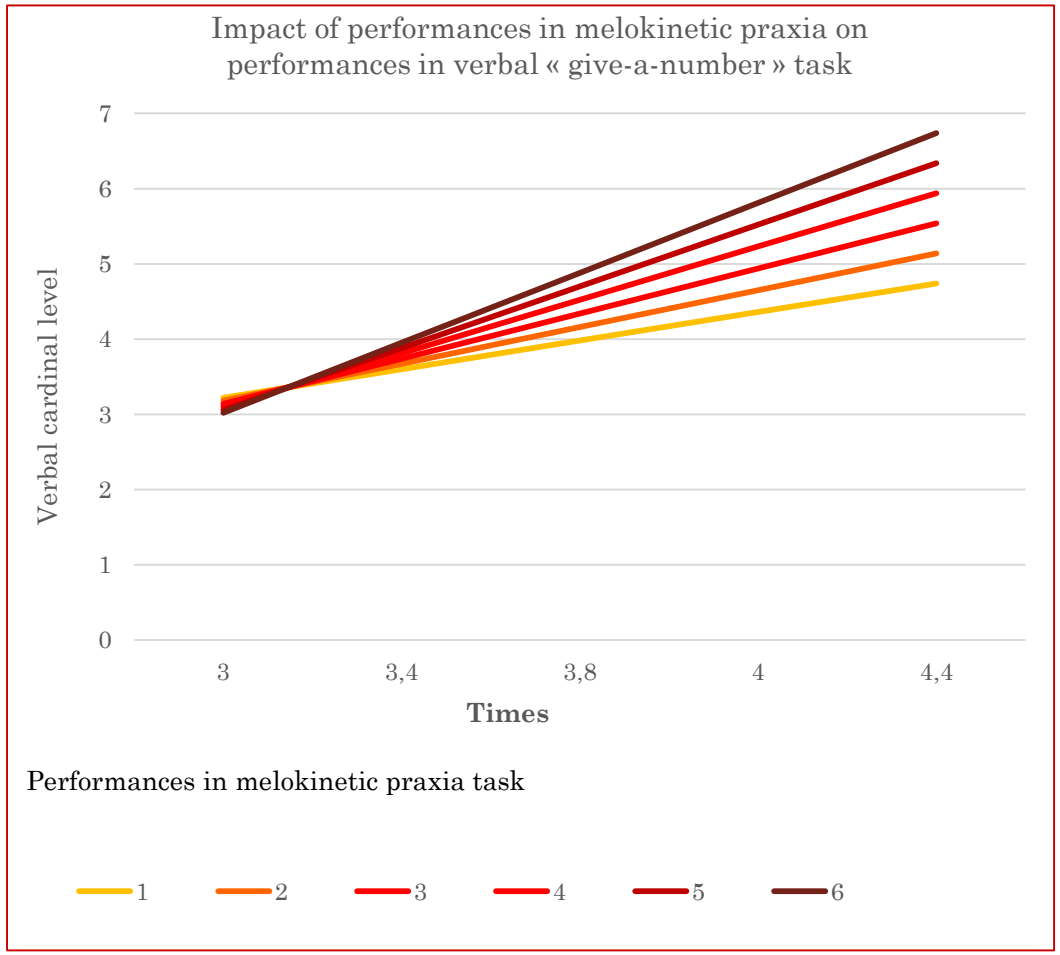
Impact of **digital imitation performances** on numerical verbal performances



Significant effect for interaction between age and digital performance

Impact of digital non-numerical skills

Impact of **melokinetic praxia performances** on numerical verbal performances



Signifiant effect for interaction

Impact of digital non-numerical skills

- Digital gnosia performance has less impact on verbal cardinal level than components of dexterity, such as dissociation skills or coordination skills

- Dissociation skills and coordination skills
  - Over time, the more efficient children are at dissociating and coordinating their fingers, the more efficient they are at understanding cardinality in verbal modality.

In conclusion

- Digital numerical performances play a role in the numerical verbal performances and this impact is modulated by the age

- Some digital non-numerical skills play a role in the verbal performance
  - Not digital gnosia skills
  - But dexterity skills (dissociation and coordination components)

- In general, the older the child is, the more this influence increases.

- Future analyses about other tasks assessing the understanding of cardinality, about other numerical skills taking part in the understanding of cardinality

- Future studies to observe the impact of these numerical and non-numerical skills on the development of arithmetic

- Future studies to observe these numerical and non-numerical skills in children with cerebral palsy, deaf, …

- Studies about the impact of the training of numerical and/or non-numerical skills

Thanks a lot to Laurence Rousselle and Marie-Pascale Noël

Thank you for your attention !