FINGER-USE AND ARITHMETIC SKILLS IN CHILDREN AND ADOLESCENTS

MCLS, 1st June 2022,
Anvers, Belgium

Maëlle Neveu
Laurence Rousselle

LA LIBERTÉ DE CHERCHER

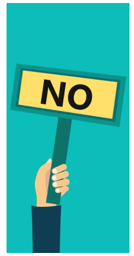
INTRODUCTION

All over the world, children use their **fingers** to perform numerical processing.

- Always available and easy to manipulate (Domahs et al., 2008)
- Provide a multisensory representation of the quantity (Domahs et al., 2008; Soylu et al., 2018)

Two main research areas → Mathematics education; Cognitive psychology and neuroscience

Inconsistent findings in these two research fields (Moeller and al. 2011).



INTRODUCTION

Mathematics education

- Some teachers prohibit finger-based strategies (Boaler & Chen, 2017; Multu et al., 2020)

  Efficiency of programs that openly descourage children from using their fingers to calculate (McKenna et al., 2005)

Cognitive psychology and neuroscience

- No association between finger skills and arithmetical abilities (Long et al., 2016; Malone et al., 2020; Newman, 2016).
- Finger skills training do not predict the development of computational skills (Schild et al., 2020).
- In preschoolers, the cardinal meaning of number gesture lag behing that of number-words (Nicoladis et al. 2010).

INTRODUCTION

Adults

- Finger counting system influence number magnitude processing (Domahs et al., 2010; Morrissey et al., 2016) and mental computation (Domahs et al., 2008; Klein et al., 2011)
- Common cerebral correlates supporting finger skills and numerical abilities:
  - ✓ Brain imaging techniques, fMRI (Andres et al., 2012; Soylu & Newman, 2016; Tschentscher et al., 2012)
  - ✓ Transcranial magnetic stimulation (Andres et al., 2007; Rusconi et al., 2005; Sato et al., 2007)

Children
(Roesch & Moeller, 2015)

- Support the segmentation of the number word sequence (Beller & Bender, 2011)
- Support counting procedure by tagging items (Alibali & DiRusso, 1999; Graham, 1999)
- Number gesture are used to communicate cardinal value of a set and learn cardinal value of new number-words (Gibson et al., 2019; Gunderson et al., 2015)
- External support for calculate (Kullberg & Björklund, 2020)

INTRODUCTION

Benefit of finger counting is mostly debated within the field of children's **arithmetic development**

Summary of all existing evidence is necessary to establish clear guidelines for teachers and therapists.

Main objective:
Identify and summarize all qualitative and quantitative studies that have investigated the relationship between **finger-use** and **arithmetic skills** in school-age children and adolescents

METHOD

Eligibility criteria

Population

Children and **adolescents** (from 3 to 17 years old)

Typical and **atypical** development

- ➢ Exclusion of acquired injuries and progressive neurological conditions

Regular and **special** education

Concept

Tasks requiring participants

- to use their fingers **physically**.
- **no contamination** by others irrelevant cognitive abilities.

Types of tasks:

- Finger-based strategies
- Finger sensorimotor skills (fine motor skills & finger gnosia)

Context

Only **arithmetic** problems solving.

- ➢ Measures clearly **identified** and **isolated**

METHOD

Sources of evidence

Type of sources

Peer-review journal articles written in **English**

- Regardless publication date

Qualitative and quantitative studies

Exclusion of Meta-analyses and reviews

Search

Literature research updated in November 2021

Data bases : Ovid PsycINFO and Ovid Eric

References lists of all included documents + reviews and meta-analyses excluded.

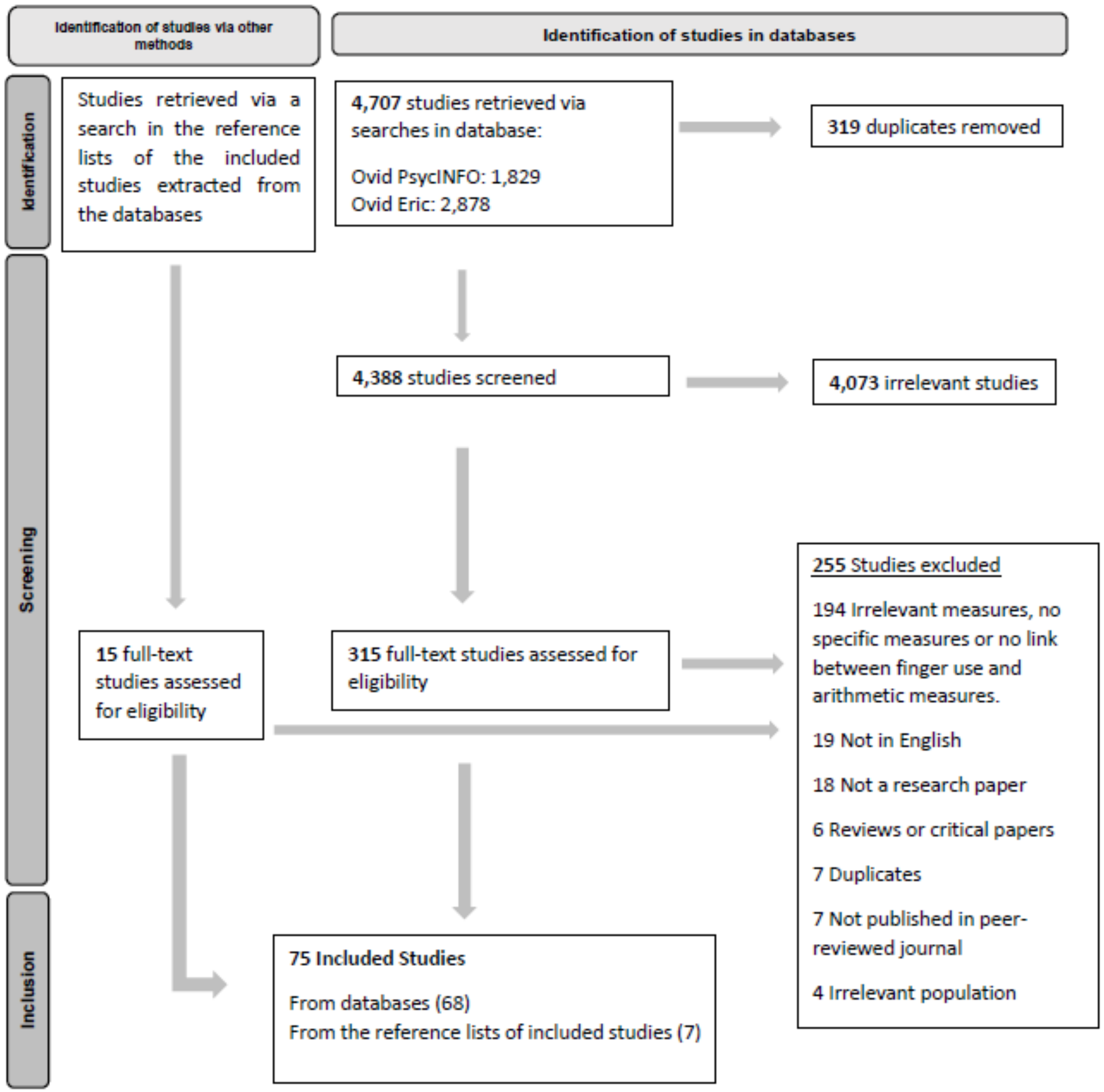
SELECTION PROCESS

PRISMA Flow chart

Selection & data collection

Done with Covidence Software by two independent researchers

Phase 1: Screening of titles and abstracts
Phase 2: Selection of full texts
Phase 3: Data collection (full texts assigned randomly, Kappa Index= .81)



DIFFERENT ISSUES IN TWO DIFFERENT FIELDS

75 publications included

37.3 %
n = 28

Finger strategies

What finger strategies?

How do they support arithmetic ?

Evolution over time

Mathematical Education

1,3 %
n = 1

61.3 %
n = 46

Neuro-functional basis

Which cognitive process?

Which neuroanatomical substrate?

Cognitive Psychology & Neurosciences

DESCRIBING FINGER-BASED STRATEGIES

Mathematical Education

n = 28

N = 6 (21.4 %)

5 qualitative st.
1 cross sectional st.

- All in TD children
- Identification of a variety of finger-based strategies to solve additions and subtractions
  - embodied representation of ordinal (finger-counting strategies) and cardinal (finger configuration/gestures) information conveyed by numbers

additions (Baroody, 1987; Fuson & Kwon, 1992; Kullberg & Björklund, 2020; Nwabueze, 2001)
subtractions (Björklund et al., 2019; Fuson & Kwon, 1992; Kullberg & Björklund, 2020; Nwabueze, 2001)

Mathematical Education

n = 28

DESCRIBING FINGER-BASED STRATEGIES

N = 6 (21.4 %)

5 qualitative st.
1 cross sectional st.

- All in TD children
- Identification of a variety of finger-based strategies to solve additions and subtractions
  - embodied representation of ordinal (finger-counting strategies) and cardinal (finger configuration gesture) information conveyed by numbers

additions (Baroody, 1987; Fuson & Kwon, 1992; Kullberg & Björklund, 2020; Nwabueze, 2001)
subtractions (Bjö ... 1)

Future directions

- Major imbalance between quantitative and qualitative designs
- Mix of spontaneous finger strategies at different ages
- Types of finger-based strategies in atypical development?

EFFICIENCY OF FINGER BASED STRATEGIES

Mathematical Education

n = 28

N = 17 (60.7%)

1 cluster RCT
5 nRCT
1 cohort st.
1 case-control st.
8 cross sectional st.
1 qualitative study

- Small to large correlations between finger use and arithmetic performance, which decreased significantly over time (K-level until 2nd-grade) (Jordan et al., 2008; Dupont-Boime, 2018)
- Spontaneous finger-based strategies in 1st- to 5th-grade TD children is related to higher-level arithmetic performance (Farrington-Flint et al., 2009; Lucangeli et al., 2003)

  > But probably different profiles of finger-users (three clusters) : (1) efficient-users (2) inefficient-users (3) unstable users (Canobi, 2004)
- Maturity of finger-based strategies related to working memory (Dupont-Boime, 2018)
- Children with MLD used finger-counting more often but were less accurate than TD children. (Geary et al., 2004)

Mathematical Education

n = 28

EFFICIENCY OF FINGER BASED STRATEGIES

N = 17 (60.7%)

1 cluster RCT
5 nRCT
1 cohort st.
1 case-control st.
10 cross sectional st.
1 qualitative study

- Explicit training of finger strategies during arithmetic > better performance both in
  - TD children in primary school (Fuson, 1986; Fuson & Secada, 1986; Fuson & Willis, 1988; Ollivier et al., 2020)
  - children with ID (Saunders et al., 2018)

Future directions

- children with atypical development (MLD, DCD, ID) under-examined : how helpful are finger-based strategies for them?

Mathematical Education

n = 28

CHANGE OVER TIME

N = 6 (21.4%)

4 cohort/longitud. st.
1 case-control st.
1 cross sectional st.

- Switching from finger-based to memory-based strategies occurs between 1st- and 3rd grade (Svenson & Sjöberg, 1982; Geary et al., 1991)
- Children with MLD switch later (Geary et al., 1991; Wylie et al., 2012; Jordan et al. ,2003)
- Chinese TD children switch earlier than American. (Geary et al., 1993)
- Unconclusive evidence the efficiency of training program to promote an earlier switch switch (one case study with two DLD children, only one switched after training) (Koponen et al. (2007)

Mathematical Education

n = 28

CHANGE OVER TIME

N = 6 (21.4%)

4 cohort/longitud. st.
1 case-control st.
1 cross sectional st.

- Switching from finger-based to memory-based strategies occurs between 1st and 3rd grade
- Children with MLD switch lat
- Chinese TD children switch e
- Unconclusive evidence the ef study with two DLD children,

Future directions

- interventions and therapeutic tools to be promoted to help children switching to memory-based strategies? Additional training studies
- Should finger use be promoted as a tool to prevent mathematics difficulties in younger children? > Longitudinal studies from preschool through primary school

FUNCTIONAL LINK : FINGER GNOSIA (FG)

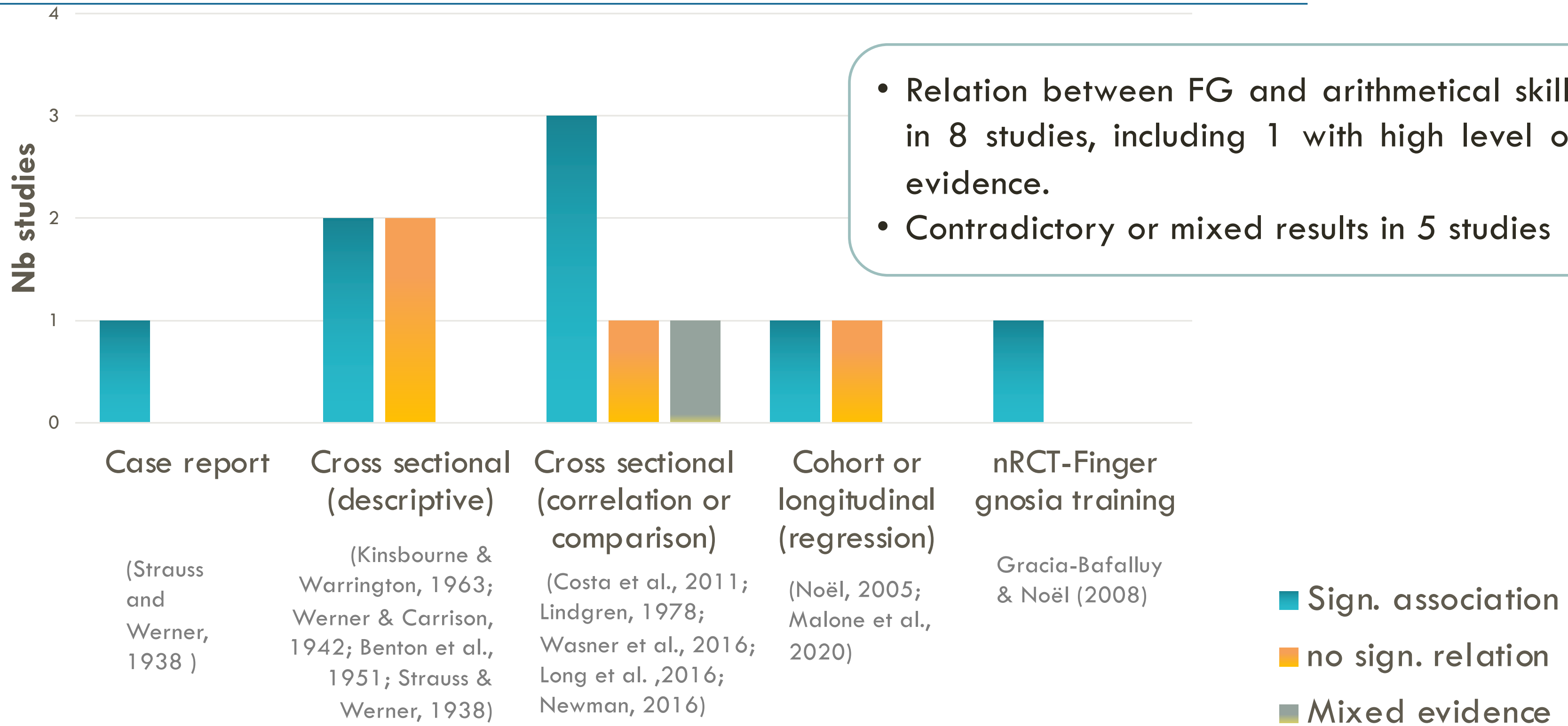
Cognitive Psychology & neurosciences

n = 46

N = 13 (28.2%)

FG & arithmetic

1 nRCT
2 cohort/longitud st.
1 case report st.
9 cross sectional st.
1 case report



- Relation between FG and arithmetical skills in 8 studies, including 1 with high level of evidence.
- Contradictory or mixed results in 5 studies

Cognitive Psychology & neurosciences

n = 46

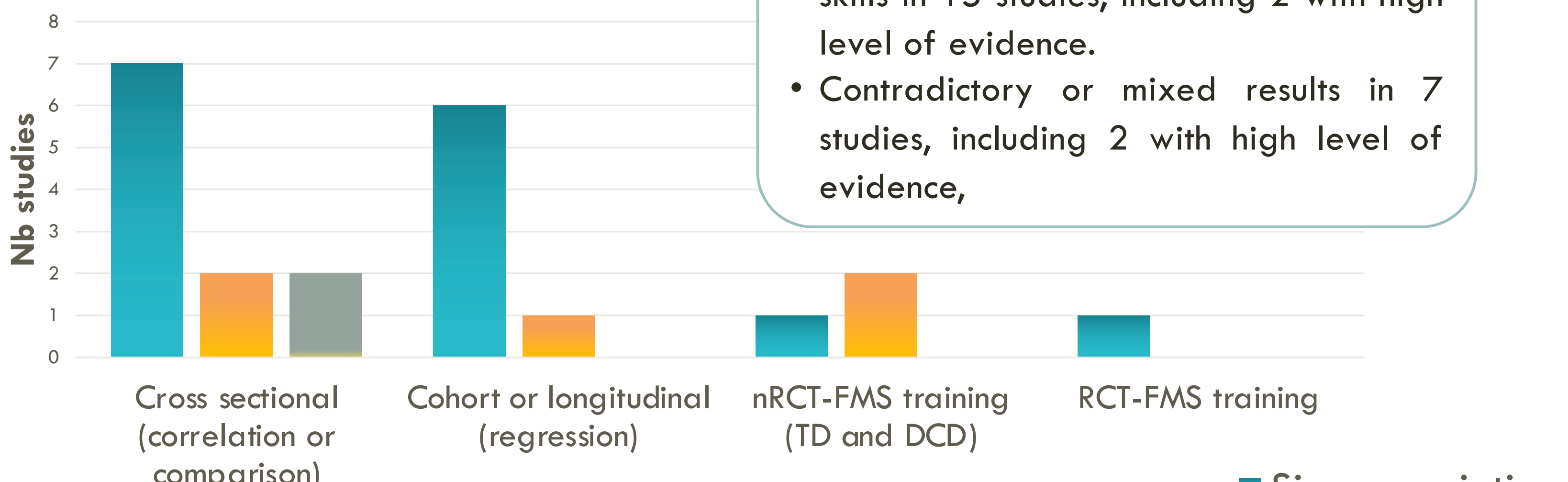
FUNCTIONAL LINK : FINE MOTOR SKILLS (FMS)

N = 22 (47.8%)

FMS & arithmetic

1 RCT
3 nRCT
7cohort/longitudin. st.
11 cross sectional st.

- Relation between FMS and arithmetical skills in 15 studies, including 2 with high level of evidence.
- Contradictory or mixed results in 7 studies, including 2 with high level of evidence,



(Annett & Manning, 1990; Dielman & Furuno, 1970; Holsti et al., 2002; Pieters, Desoete, Roeyers, et al., 2012; Pieters, Desoete, Waelvelde, et al., 2012; Raghubar et al., 2015; VanRooijen et al., 2012)

(Asakawa & Sugimura, 2014; Barnes et al., 2011; Dinehart & Manfra, 2013; Jenks et al., 2009; Siegel, 1992; Van Rooijen et al., 2015; Michel et al., 2020)

Zafranas, 2004; Costa-Giomi, 2004; Alloway & Warner, 2008)

(Asakawa et al., 2019)

FUNCTIONAL LINK : FINE MOTOR SKILLS (FMS)

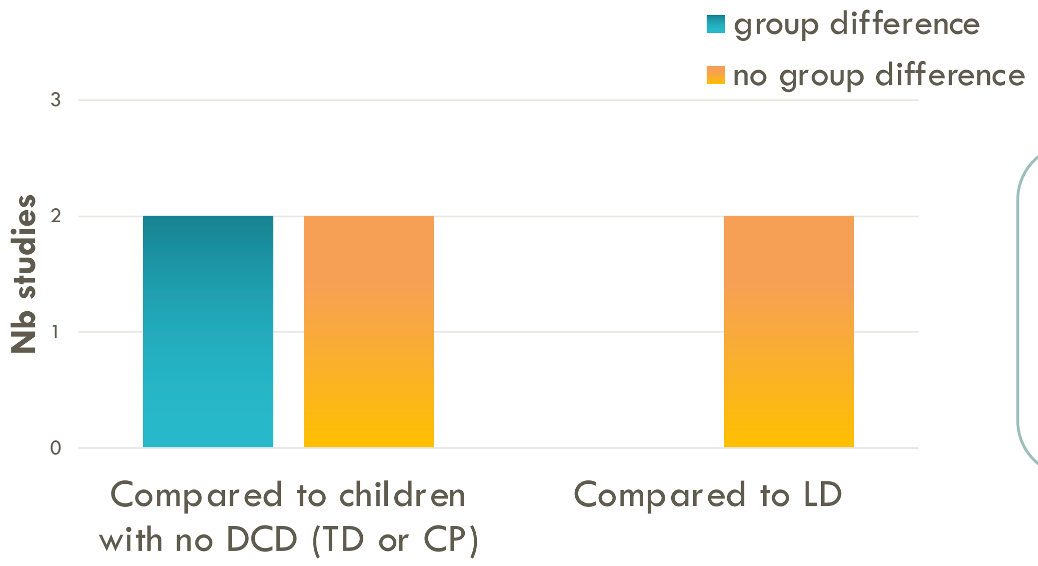
Cognitive Psychology & neurosciences

n = 46

N = 6 (13%)

Congenital or developmental coordination disorders (DCD)

6 cross sectional st.
Comparison of children with DCD (with or without CP) to other groups (LD, CP with non DCD, or TD)



(Roberts et al, 2011; Gomez et al., 2015) (Reynvoet et al., 2020; Thevenot et al., 2014)

(Alloway & Archibald, 2008; Alloway & Temple, 2007)

Mixed evidence

Many other uncontrolled factors

FUNCTIONAL LINK : OTHER FINGER ABILITIES

Cognitive Psychology & neurosciences

n = 46

N = 7 (15.2%)

2 RCT,
1 longitudinal study
4 cross sectional study

Other finger abilities and arithmetic

- Relation between finger tapping (motor timing control) and arithmetic achievement (Waber et al., 2000)
- Sequence of rhythmic hand movement > not a predictor of arithmetic achievement (Asakawa & Sugimura, 2014)
- Limiting/interfering finger movement impede arithmetic performance, especially in younger learners > motor planning (Cho & So; 2018; Crollen & Noël, 2015)

Cognitive Psychology & neurosciences

n = 46

FUNCTIONAL LINK : OTHER FINGER ABILITIES

N = 7 (15.2%)

Other finger abilities and arithmetic

2 RCT,
1 longitudinal study
4 cross sectional study

- Relation between finger tapping (motor timing control) and arithmetic achievement

(Waber et al., 2000)

- Sequence of rhy

14)

- Limiting/interfe
younger learne

5)

Future directions

Majority of studies suggesting a relationship between FG or FMS and arithmetic but supported by only 60% of RCT and nRCT

- What about the causal links between FMS or finger gnosia and arithmetic skills ?
- What about other components of fine motor skills? Manual dexterity? finger isolation? Finger motility, coordination?

NEURONAL SUBSTRATE

Cognitive Psychology & neurosciences

n = 46

N = 2 (4.3%)

Typically developing children

2 cross sectional study

Finger-related brain areas (FMS)

- more activated during calculation than during a magnitude comparison task

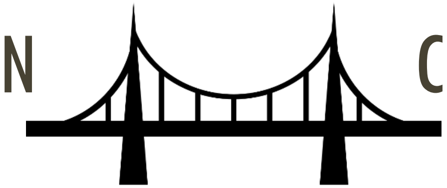
(Krinzinger et al., 2011

- more activated than the finger somatosensory area (FG) during subtraction in children between 8 and 13 years old

Berteletti and Booth (2015)

Future directions

fMRI study to examine how the cerebral activities related to arithmetic is modulated by finger training.

MATHEMATICAL EDUCATION  COGNITIVE PSYCHOLOGY

Reeve & Humberstone (2011)
5 to 7 year old TD

Four different subgroups based on arithmetic achievement and the frequency of finger use during calculation

- low finger user/low achievers
- low finger user/high achievers
- high finger user/medium achievers
- medium finger user / medium achievers)

Four finger gnosia profiles

- finger/hand confusion,
- finger confusion
- medium finger gnosia
- high finger gnosia.

significant relationship between finger gnosia profiles, finger use and arithmetic achievement beyond the contribution of visuospatial working memory (large effect size)

MATHEMATICAL EDUCATION COGNITIVE PSYCHOLOGY

Reeve & Humberstone (2011)
5 to 7 year old TD

Four different subgroups
arithmetic achievement and
of finger use during ca

- low finger user/low achiev
- low finger user/high achie
- high finger user/medium a
- medium finger user / medi

Future directions

- Do finger sensorimotor skills play a role
  - In the efficiency of finger-based strategies
  - in the switch to more advanced strategies?
- How and when training finger abilities should be implemented at school, in addition to finger counting training?
- What are the most effective finger-based strategies to be targeted as a function of cognitive profile (TD or aTD)

gnosia profiles

d confusion,
usion
ger gnosia
gnosia.

CONCLUDING REMARKS

- Still a lot of work!
- Need for higher level of evidence at all level
- Need to examine the link between finger use and arithmetic in children with atypical development (DCD, MLD, intellectual disability, sensory impairment)
- More attention to children enrolled in special education curriculum
- Need to make bridge between both research field to promote best practice in education and clinical intervention