ICT in primary education of mathematics

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20.4.2011

QUESTIONS

1) What new do we know about learning basic skills in mathematics ?
2) What do we really know about computer-assisted instruction of basic mathematical skills ?
3) What should I take into account, when I select computer assisted tools for my classroom ?

WHAT NEW DO WE KNOW ABOUT LEARNING BASIC SKILLS IN MATHEMATICS ?

WHAT KIND OF THINGS SHOULD INCLUDED IN COMPUTER-ASSISTED INSTRUCTION OF BASIC MATHEMATICAL SKILLS ?

Source: Räsänen & Koponen (2010). NMI-Bulletin.

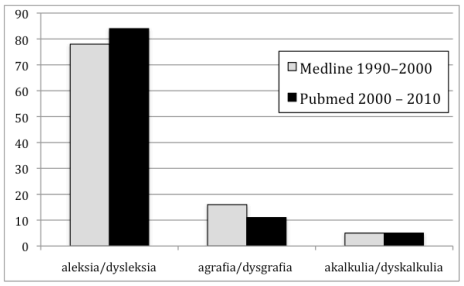

Figure 1. Ratios of neuropsychological research on reading, writing and mathematical cognition between 1990–2000 (Ardila & Roselli, 2002) and 2000–2010 (Räsänen & Koponen, 2010).

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Educational neuroscience

- neuroscientific research has changed and will change our understanding what learning is
- in reading, e.g.
  - BIG THEORETICAL AND PRACTICAL CHANGES: importance of phonological awareness and skills
  - BETTER UNDERSTANDING OF SMALL DETAILS: why children produce mirror images in reading and writing

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Educational neuroscience

- How educational neuroscience is changing our understanding of numerical cognition ?
- BIG THEORETICAL AND PRACTICAL CHANGES: understanding how brains process magnitudes and relations between magnitudes
- SMALL DETAILS: representations of number line

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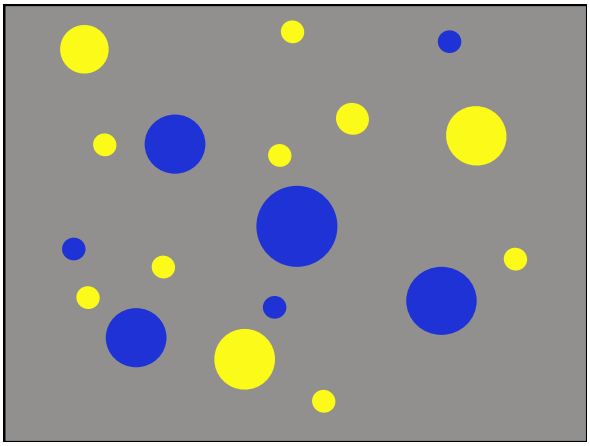
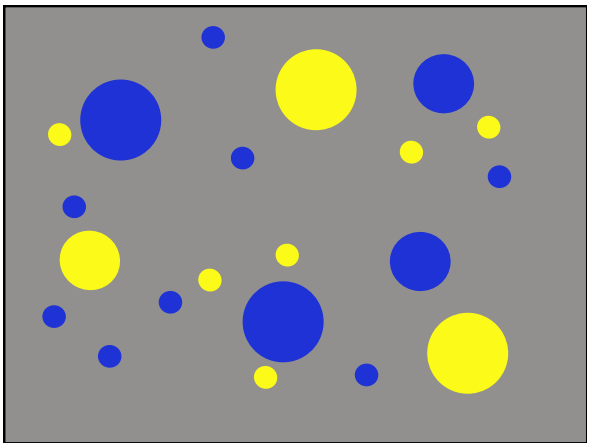
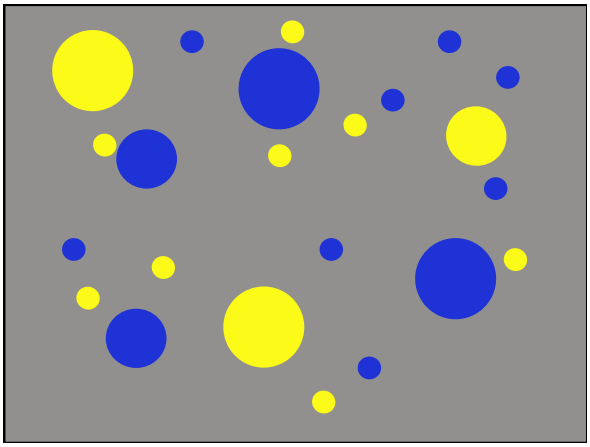
Short introduction current research on mathematical cognition

- How do we process the MEANING of numbers
  - implications to education
  - implications to special education







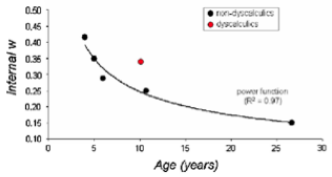


Fig. 3. Developmental trajectory of *w*. The graph represents mean *w* as a function of mean age and group. In black, developmental trajectory for the non-dyscalculic group. In red, mean *w* for the dyscalculic group, whose performance is equivalent to that of 5 years younger non-dyscalculic controls. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Piazza, M. (2010). Developmental trajectory of number acuity reveals a severe impairment in developmental dyscalculia. Cognition, 116, 33–41.

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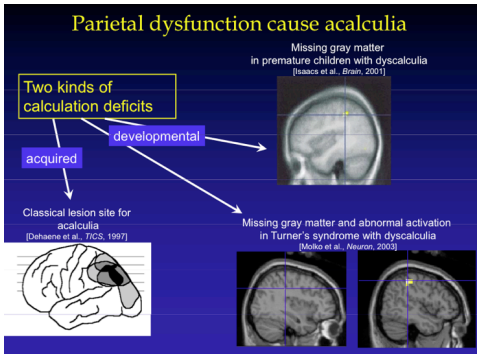

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See also: Impaired parietal magnitude processing in Developmental Dyscalculia
Price, Holloway, Räsänen, Vesterinen, & Ansari (2008) *Current Biology*

Representations of magnitude

- Even 4–5 year old children understand the concept of addition and subtraction with large quantities (Barth et al., 2005, 2006)
  - even though they can not calculate the exact answers or even name the numbers correctly
  - this basic understanding of quantities is not explicitely taken into focus of education, but assumed to be self-evident for children

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Representations of magnitude

- forms the foundation of basic numerical understanding
- can not be found from school books or curriculums
- the whole question absent in teacher education
- some new CAI games have implemented these ideas

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Representations of numbers

- Meaning, i.e. understanding the "size" is based on similar or intertwined mechanism as the representation of magnitudes is
- Size of number is scale and context dependent
- E.g. is 8 large or small
  - In scale 1-10 or compared to 4: large
  - In scale 1–100 or compared to 55: small

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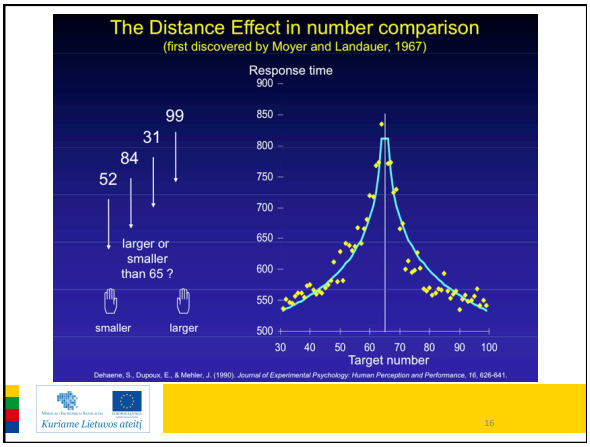
The Distance Effect in number comparison
(first discovered by Moyer and Landauer, 1967)
Response time
99
31
84
52
larger or smaller than 65 ?
smaller
larger
900
850
800
750
700
650
600
550
500
30 40 50 60 70 80 90 100
Target number
Dehaene, S., Dupoux, E., & Mehler, J. (1990). Journal of Experimental Psychology: Human Perception and Performance, 16, 626-641.
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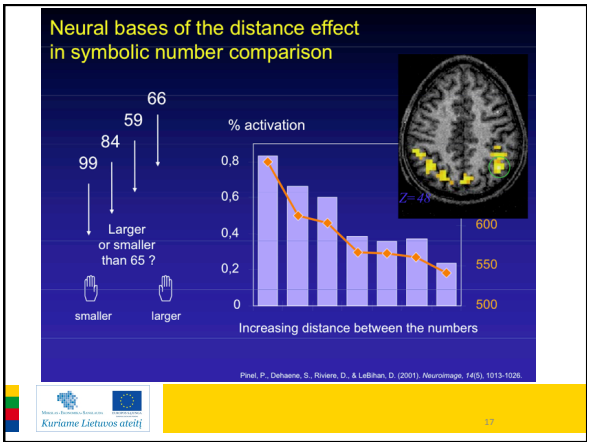
Neural bases of the distance effect
in symbolic number comparison
66
59
84
99
Larger or smaller than 65 ?
smaller
larger
% activation
0,8
0,6
0,4
0,2
0
600
550
500
Increasing distance between the numbers
Pinel, P., Dehaene, S., Riviere, D., & LeBihan, D. (2001). Neuroimage, 14(5), 1013-1026.
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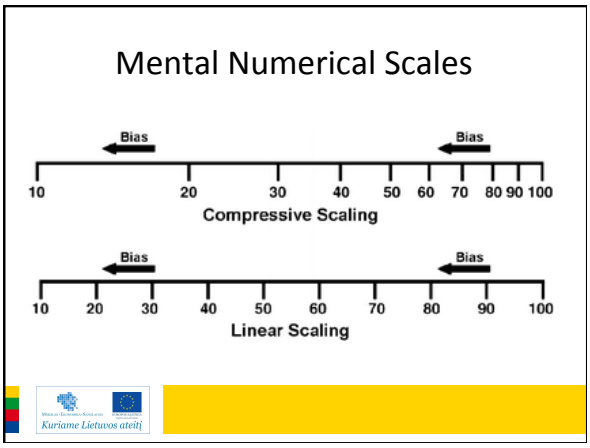
Mental Numerical Scales
Bias
Bias
10 20 30 40 50 60 70 80 90 100
Compressive Scaling
Bias
Bias
10 20 30 40 50 60 70 80 90 100
Linear Scaling
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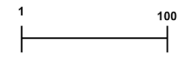
Development of the linear understanding of number

(Siegler & Opfer, 2003; Siegler & Booth, 2004)

Number-Space mapping task:
« Please point to where number x should fall »



A major change occurs during mathematical education : switch from a logarithmic to a linear understanding of number

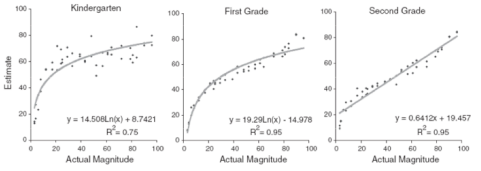


Figure 2. Progression from logarithmic pattern of median estimates among kindergartners (left panel) to linear pattern of estimates among second graders (right panel) in Experiment.

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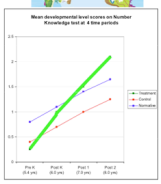
Playing board games promotes arithmetic in low-SES kindergartners

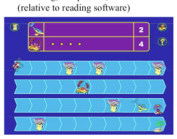
Griffin & Case (1994, 2004)

Training with a curriculum involving board games leads to long-lasting improvements

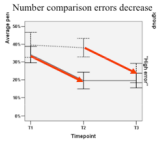


Wilson & Dehaene (2007), with Fayol

NumberRace Software improves subitizing, comparison, identification (relative to reading software)

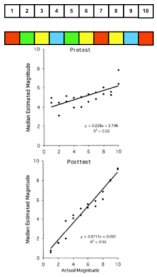


Number comparison errors decrease



Ramani & Siegler (2008)

Very brief training leads to improvements in number-space mapping, comparison, identification, counting (relative to control game)



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Small details

- Even small details in number line training may matter
  - e.g. ”counting from 1” vs. ”counting on” in board game training (Laski, 2011)
    - counting from 1: no learning effect to math skills
    - counting on: clear learning effect to math skills
  - compare: addition strategies
  - solution strategies not usually controlled in CAI

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DO WE HAVE EVIDENCE BASED EDUCATION ?

What do we really know about computer-assisted instruction of basic mathematical skills ?

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CAI

- There is more than 1000 programs for math education
- about a same amount of math education related web pages with materials or illustrations
- how much do we have controlled studies on these applications ?

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Computers & Education 53 (2009) 913–928

Contents lists available at ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

Analysis of studies of the effects of computer-assisted instruction on the mathematics performance of students with learning disabilities

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ARTICLE INFO

Article history:
Received 6 March 2009
Received in revised form 1 May 2009
Accepted 4 May 2009

Keywords:
Computer-assisted instruction
Students with learning disabilities
Mathematics
Meta-study

ABSTRACT

The purpose of this study was to conduct a meta-study of computer-assisted instruction (CAI) studies in mathematics for students with learning disabilities (LD) focusing on examining the effects of CAI on the mathematics performance of students with LD. This study examined a total of 11 mathematics CAI studies, which met the study selection criterion, for students with LD at the elementary and secondary levels and analyzed them in terms of their comparability and effect sizes. Overall, this study found that those CAI studies did not show conclusive effectiveness with relatively large effect sizes. The methodological problems in the CAI studies limit an accurate validation of the CAI's effectiveness. Implications for future mathematics CAI studies were discussed.

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Results

- database search (Psyinfo, Education Full Text, Academic Search Premier, Google Scholar, Educational Resources Information Center (ERIC)) from January 1980 to September 2008
- only 11 controlled studies found with appropriate data published
- Räsänen et al. (2009) analysed 5 of these studies which were targeted to primary grades

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Targets of math CAI (in Bloom's taxonomy)

	Cognitive processes					
Knowledge dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge						
Conceptual Knowledge						
Procedural Knowledge						
Meta-Cognitive Knowledge						

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Räsänen, P., Salminen, J., Wilson, A., Aunio, P., & Dehaene, S. (2009). Computer-assisted intervention for children with low numeracy skills. Cognitive Development, 24, 450–472.

Effect sizes for CAI on early numbers skills (6–9y) on different types of interventions in groups of children with SEN

ES= 0.67
(CI= -0.15–1.49)

Table 1
Effect sizes with sample size correction (Hedges and Olkin, 1985) and confidence intervals for effect sizes calculated from the difference in gains between CAI and control groups in five studies.

Study	n	Task	Effect Size	Confidence Interval for Effect Size	
				Lower	Upper
Ortega-Tudela and Gómez-Ariza (2006)	18	Correspondence	0.86	−0.11	1.83
		Stable order (10)	1.33	0.30	2.36
		Cardinality	0.91	−0.06	1.89
		Stable order (20)	1.38	0.35	2.42
		Give X	2.88	1.56	4.21
Christensen and Gerber (1990)	30	Written addition, LD	0.61	−0.12	1.34
		Written addition, ND	0.41	−0.31	1.14
		Oral addition, LD (time)	0.52	−0.21	1.24
		Oral addition, ND (time)	−0.05	−0.76	0.67
Clements (1986)	24	CAI vs. Logo in Math	0.54	−0.27	1.36
		CAI vs. Control in Math	0.55	−0.27	1.36
		CAI vs. Logo in Classification	1.28	0.40	2.15
		CAI vs. Control in Classification	0.14	−0.66	0.94
		CAI vs. Logo in Seriation	1.55	0.64	2.47
		CAI vs. Control in Seriation	−0.25	−1.05	0.55
Fuchs et al. (2006)*	33	Addition fact	0.95	0.23	1.67
		Subtraction fact	−0.01	−0.69	0.67
		Story problems	−0.12	−0.80	0.56
Shin et al. (2006)	37	Addition and subtraction	0.29	−0.36	0.94
		Basic Addition and subtraction	0.36	−0.29	1.01
		Advanced Add. and subtraction	−0.07	−0.72	0.57
Total	184		0.67	−0.15	1.49

Note: LD: Learning disabled; ND: normal development.
* Fuchs et al. (2006) used the correction for the correlation between the pre- and post-measurement (see Glass, McGaw, & Smith, 1981) in their own analysis.

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Kavale, K.A. (2007). Quantitative Research Synthesis: Meta-Analysis of Research on Meeting Special Educational Needs. In Lani Florian (Ed.) Handbook of special education. Sage Publications.

Effective Instructional Practices	Mean Effect Size
Mnemonic Instruction	1,62
Self-Monitoring	1,36
Reinforcement	1,17
Self-Questioning	1,16
Drill & Practice	0,99
Strategy Instruction	0,98
Feedback	0,97
Direct Instruction	0,93
Visual Displays	0,90
Computer-Assisted Instruction	0,87
Repeated Reading	0,76
Error Correction	0,72
Early Intervention	0,71
Formative Evaluation	0,70
Peer Mediation	0,64
Diagnostic-Prescriptive Teaching	0,64
Peer Tutoring	0,62
Positive Class Morale	0,60
Grouping	0,43
Cooperative Learning	0,40
Increased Time	0,38

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Kulik, J.A. (1994). Meta-analytic studies of findings on computer-based instruction. In Baker & O'Neil (eds.) Technology assessment in education and training. NJ: Lawrence Erlbaum.

Average ES of CAI in elementary schools was .32 (SD=.39). This means about 3 months gain due to CAI.

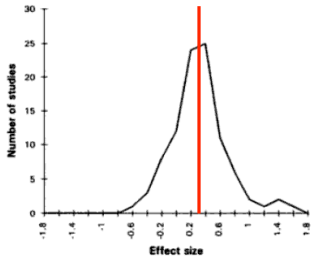

FIG. 1.1. Effects of computer-based instruction on examinations in 97 studies.

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Starting to use CAI

What should I take into account, when I select computer assisted tools for my classroom ?

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BENEFITS of CAI

- Visualisation ?
- Individualisation ?
- Feedback ?
- New educational methods

Visualisation

- Computers allow visualising mathematics
- visualisation vs. concrete manipulatives
- playing with concrete 3D materials seems to be a better choice than with their 2D illustrations on computers
  - exception: complex modeling in upper grades

Individualisation

- Computers allow individualisation of education via two ways
  - one-to-one HCI with selected content
  - adaptation implemented in the application
- hugh economical advantage over teacher-child interaction (TCI)
- TCI beats HCI as a teaching method
- problem: limited evidence on effective ways of adatation

Feedback

- Computers can give IMMEDIATE feedback
  - not possible in classroom settings
- Different types of feedback not studied properly
- Most of the CAI applications give only correcting or motivating feedback

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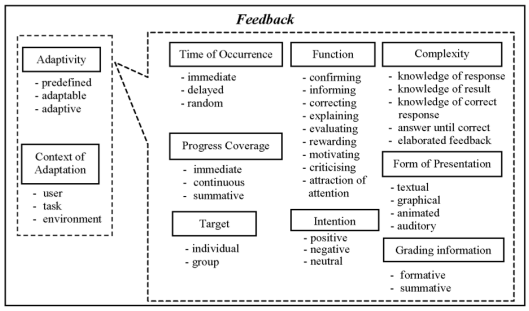
Taxonomy of the system's feedback concept



Vasilyeva, I., Puuronen, S., Pechenizkiy, M., & Räsänen, P. (2007). Feedback Adaptation in Web-based Learning Systems. International Journal of Continuous Engineering Education and Life-Long Learning, 17(4/5), 337 – 357.

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neure

An example: Subtraction

- You can directly try the example task in net
  - unfortunately instructions currently only in Finnish
- Implemented in a web-based educational java environment (run by National Board of Education and NMI)
- http://www2.edu.fi:80/neure/pub/login.do?j_username=neuredemo&j_password=demo

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Subtraction task

- CAI task to train subtraction 0–18
  - adapts to child's skill level
  - gives support via illustrations
- Levels:
  - concrete
  - numberline
  - strategy
  - automatisation (increased time pressure)

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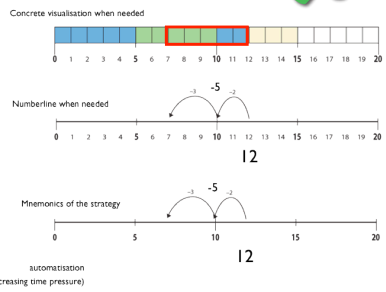
Example

12 – 5 = 7



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Subtraction

- Adaptation
  - 3 dimension
  - 1: type of visualisation (implemented in levels)
  - 2: size of minuend (within each training session)
  - 3: size of answer (within each training session)
    - correct answer: values of Minuend and Answer will grow
    - incorrect answer: values of Minuend and Answer will become smaller

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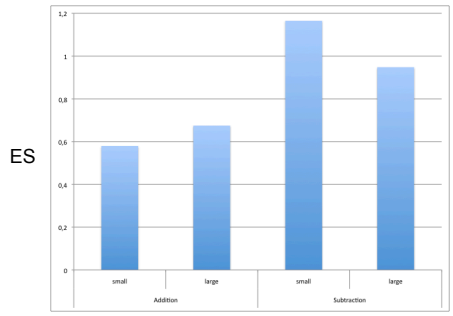
Subtraction - pilot study (n=10)



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Starting to use CAI

SUMMARY

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Summary: ICT in basic math education

- limited support from research
- strategic and cognitive models of teaching outperform CAI in effectiveness
- concrete better than their CAI illustrations
- useful in well-aimed purposes: drill-and-practice tasks with proper feedback and adaptation

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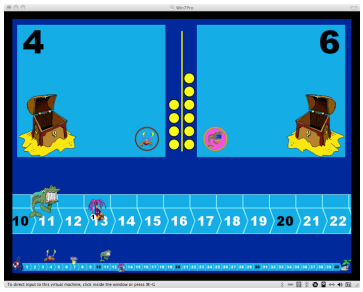
Summary: ICT in basic math education

- benefit in special education
  - allows individualisation and saves human resources
- current applications limited in their "educational depth"
  - traning targeted to factual and procedural memory
- CAI best when combined with teacher offering conceptual, strategic and metacognitive training in understanding and applying math contents

Advertisement

- version 3 of the NumberRace game will appear in summer 2011
  - combined magnitude and number comparison and numberline training
  - open source: free to use, free for translations



Thank you !

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