

# Development of components of mathematics in 7-to-11-year-old children: a study using Dynamo Assessment

(Dyscalculia and Developmental Delays)

Dr Ann Dowker, Department of Experimental Psychology, Oxford University;

Karima Esmail, Dynamo Maths

BSRLM: British Society for Research into Learning Mathematics

Date: 04 March 2017



British Society for  
Research into  
Learning Mathematics

[www.bsrlm.org.uk](http://www.bsrlm.org.uk)



[www.ox.ac.uk](http://www.ox.ac.uk)



[www.dynamomaths.co.uk](http://www.dynamomaths.co.uk)

# Dynamo Assessment

- Dynamo Assessment is a computer based assessment that takes into account the componential nature of mathematics (Dowker 2005).
- It has been developed on a NumberSenseMMR™ Framework.
- Dynamo Assessment identifies the mathematical components which the children would be struggling with so that this detailed profile may be used for intervention.
- A sample of the first part of the Assessment, outlining the 14 components of mathematics assessed by the Assessment can be seen in Figure 3.1.
- (The first component is a general measure of reaction time in an orientation task. It is not discussed in the present talk.)



British Society for  
Research into  
Learning Mathematics [www.bsrlm.org.uk](http://www.bsrlm.org.uk)



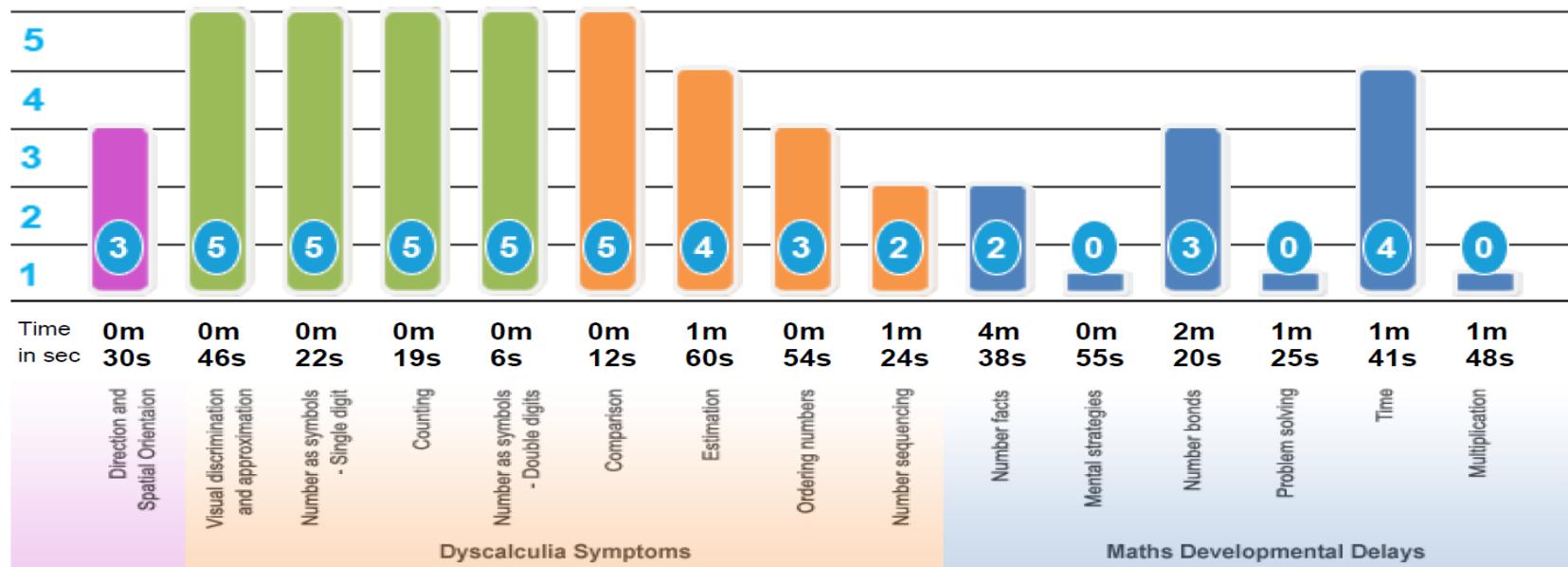
[www.ox.ac.uk](http://www.ox.ac.uk)



[www.dynamomaths.co.uk](http://www.dynamomaths.co.uk)

# Dynamo Assessment

## NUMBER SENSE DEVELOPMENT PROFILE



Dyscalculia Symptoms

Developmental Delays



British Society for  
Research into  
Learning Mathematics [www.bsrlm.org.uk](http://www.bsrlm.org.uk)



[www.ox.ac.uk](http://www.ox.ac.uk)



[www.dynamomaths.co.uk](http://www.dynamomaths.co.uk)

# NumberSenseMMR™ Framework

- The tests were grouped into Number Magnitude, Number Meaning and Number Relationships adding the scores for the tests in each group.
- **Number Meaning: Visual** discrimination and Approximation; Number as Symbols-Single-digit; Counting and Number as Symbols –Double digit.
- **Number Magnitude: Comparison**; Number Sequencing; Estimation and Ordering Numbers
- **Number Relationships: Number** Facts; Mental Strategies; Number Bonds; Problem Solving; Time; Multiplication
- **Dyscalculia Symptoms:** Number Meaning and Number Magnitude
- **Developmental Delays:** Number Relationships



British Society for  
Research into  
Learning Mathematics [www.bsrlm.org.uk](http://www.bsrlm.org.uk)



[www.ox.ac.uk](http://www.ox.ac.uk)



[www.dynamomaths.co.uk](http://www.dynamomaths.co.uk)

# Background

- This assessment has so far been predominantly used as a way of diagnosing the components suitable for intervention in children with mathematical difficulties.
- Interventions based on the assessment have shown promising initial results (Zerafa & Dowker, 2016).
- A current aim is to standardize the measure, to find age norms for typically developing children.
- For this purpose, 2385 children between 7 and 11 were given the assessment.



British Society for  
Research into  
Learning Mathematics [www.bsrlm.org.uk](http://www.bsrlm.org.uk)



[www.ox.ac.uk](http://www.ox.ac.uk)



[www.dynamomaths.co.uk](http://www.dynamomaths.co.uk)

# Aims of the present study

- To what extent do children improve with age in scores and reaction times in the three groups of tests?
- Do age groups differ only on the Number Relationships tests, while showing ceiling effects on the others; or do they differ on all groups of tests?
- To what extent do the different groups of tests correlate with each other?
- To what extent do scores correlate with reaction times?



# Assumptions

- The assumption in the diagnostic use of the assessment has been that Number Magnitude and Number Meaning represent aspects of ‘number sense’ that are impaired in children with significant mathematical disabilities that may be termed ‘dyscalculia’.
- Number Relationships may represent arithmetical understanding that is more dependent on school instruction, and may be delayed in children with no underlying mathematical disabilities.
- In the present study, however, no assumption is made about the underlying causes of differences in performance on these components.



# Participants

- The children included:
  - 280 seven-year-olds.
  - 627 eight-year-olds
  - 594 nine-year-olds
  - 526 ten-year-olds
  - 358 eleven-year-olds
- 
- 48% girls; 52% boys



British Society for  
Research into  
Learning Mathematics [www.bsrlm.org.uk](http://www.bsrlm.org.uk)



[www.ox.ac.uk](http://www.ox.ac.uk)



[www.dynamomaths.co.uk](http://www.dynamomaths.co.uk)



# Scores and reaction times

- In this study, there were two aspects of the three groups of tests that were analysed:
- (1) Each child's combined **scores** on the tests in each group.
- (2) The combined **mean reaction times** of each child to the tests in each group. (Only reaction times for correct answers were included.)



British Society for  
Research into  
Learning Mathematics [www.bsrlm.org.uk](http://www.bsrlm.org.uk)



[www.ox.ac.uk](http://www.ox.ac.uk)



[www.dynamomaths.co.uk](http://www.dynamomaths.co.uk)

# Correlations between scores.

- In the group of 2385 children, all correlations between Number Magnitude, Number Meaning and Number Relationship scores were significant at the 0.01 level.



British Society for  
Research into  
Learning Mathematics

[www.bsrlm.org.uk](http://www.bsrlm.org.uk)



[www.ox.ac.uk](http://www.ox.ac.uk)



[www.dynamomaths.co.uk](http://www.dynamomaths.co.uk)

# Analysis of Variance for Scores

- A Between Participants Analysis of Variance was carried out, with Age Group as the between-participants factor, and Number Magnitude Score, Number Meaning Score Number Relationships and Number Relationships score as the dependent variables.



British Society for  
Research into  
Learning Mathematics

[www.bsrlm.org.uk](http://www.bsrlm.org.uk)



[www.ox.ac.uk](http://www.ox.ac.uk)



[www.dynamomaths.co.uk](http://www.dynamomaths.co.uk)

# Effects of Age Group on Number Magnitude scores

- There was a highly significant effect of Age on Number Magnitude score ( $F(4,2381)= 24.467$ ;  $p = 0.001$ ).
- The mean scores were 12.18 (s.d. 4.74) out of 20 for 7-year-olds; 11.78 (s.d. 4.75) for 8-year-olds; 12.87 (s.d. 5.177) for 9-year-olds; 14.038 (s.d. 6.63) for 10-year-olds; and 14.54 (s.d. 5.48) for 11-year-olds.
- Tamhane 2 post hoc tests showed that there were no significant differences between 7 - and 8-year-olds, 7 - and 9- year-olds, or 10-and 11-year-olds; but there were highly significant differences between 7 - and 10-year-olds, 7 and 11-year-olds, 8- and 9-year-olds, 8- and 10-year-olds, 8- and 11-year-olds, 9-and 10-year-olds and 9-and 11-year-olds.
- All significant differences were in the direction of older children scoring higher.



# Effect of Age Group on Number Meaning scores

- There was a highly significant effect of Age on Number Meaning score ( $F(4,2381) = 13.26$   $p = 0.001$ ).
- The mean scores were 14.038 (s.d. 5.198) for 7-year-olds; 14.54 (s.d. 1.66) for 8-year-olds; 18.65 (s.d. 2.113) for 9-year-olds; 18.99 (s.d. 1.76) for 10-year-olds; and 19.3 (s.d. 1.39) for 11-year-olds.
- Tamhane 2 post hoc tests showed that there were no significant differences between 7 - and 8-year-olds, 8- and 11-year-olds, 9- and 10-year-olds, 9- and 11-year-olds or 10- and 11-year-olds.
- But there were highly significant differences between 7 - and 9-year-olds, 7 - and 10-year-olds, 7 and 11-year-olds and 8- and 10-year-olds, 9- and 10-year-olds and 9- and 11-year-olds.
- All significant differences were in the direction of older children scoring higher.



# Effects of Age Group on Number Relationships scores

- There was a highly significant effect of Age on Number Relationships score ( $F(4,2381)= 12.86$ ;  $p = 0.001$ ).
- The mean scores were 9.54 out of 30 (s.d. 6.976) for 7-year-olds; 9.776 (s.d. 7.15) for 8-year-olds; 10.007(s.d. 6.74) for 9-year-olds; 19.41 (s.d. 1.35 for 10-year-olds; and 19.28 (s.d. 7.1) for 11-year-olds.
- Tamhane 2 post hoc tests showed that there were no significant differences between 7 - and 8-year-olds, 7 - and 9- year-olds , 8-and 9-year-olds or 10-and 11-year-olds.
- But there were highly significant differences between 7 - and 10-year-olds, 7 and 11-year-olds, , 8- and 10-year-olds, 8- and 11-year-olds, 9-and 10-year-olds and 9- and 11-year-olds.
- All significant differences were in the direction of older children scoring higher.



British Society for  
Research into  
Learning Mathematics

[www.bsrlm.org.uk](http://www.bsrlm.org.uk)



[www.ox.ac.uk](http://www.ox.ac.uk)



[www.dynamomaths.co.uk](http://www.dynamomaths.co.uk)

# Summary of findings for scores

- **There was a strong improvement** with age on all groups of tests.
- For both Number Magnitude and Number Relationships, the biggest age differences were between 7-to-9-year-olds and 10-to 11-year-olds.
- For Number Meaning, the biggest age differences seem to be between 7-year-olds and older children, and between 9-year-olds and older children.
- This could, however, reflect a tendency for ceiling effects in the older children for Number Meaning.



# Summary of findings for scores

- To investigate the effect of Number Magnitude and Number Meaning on school-type mathematical learning (Number Relationships), an entry-type multiple regression was carried out on Number Relationships.
- The predictor variables included were Number Meaning, Number Magnitude, Game Score and Age in years.
- Number Magnitude was a highly significant predictor (beta = 0.313;  $t = 12.92$ ;  $p < 0.001$ ).
- Number Meaning was also a highly significant predictor (beta = 0.091;  $t = 3.784$ ;  $p < 0.001$ ).
- Age was also significant (beta = 0.48;  $t = 2.46$ ;  $p = 0.014$ ).
- Game Score did not reach independent significance (beta = 0.036;  $t = 1.85$ ;  $p = 0.064$ ).





# Reaction Times

- Number Magnitude Combined Reaction Time, Number Meaning Combined Reaction Time and Number Relationships Combined Reaction Time correlated significantly with one another and with the test scores ( $p < 0.1$  in all cases).
- Number Meaning Reaction Time correlated negatively with Number Relationships Reaction Time, but the other reaction time correlations were positive.
- One would have expected all reaction times would correlate negatively with the scores (the faster you were, the better you'd do).
- This was so for Number Meaning Combined Reaction Time; and also for Number Magnitude Combined Reaction Time.
- But Number Relations Combined Reaction Time correlated positively with all scores.



# Reaction Time Analysis of Variance

- A Between Participants Analysis of Variance was carried out, with Age Group as the between-participants factor, and Number Magnitude Combined Reaction Time, Number Meaning Combined Reaction Time and Number Relationships Combined Reaction Time as the dependent variables.



British Society for  
Research into  
Learning Mathematics

[www.bsrlm.org.uk](http://www.bsrlm.org.uk)



[www.ox.ac.uk](http://www.ox.ac.uk)



[www.dynamomaths.co.uk](http://www.dynamomaths.co.uk)

# Effects of Age Group on Number Magnitude Combined Reaction Time

- There was a highly significant effect of Age on Number Magnitude Number Magnitude Combined Reaction Time ( $F(4,2381)= 14.99$   $p = 0.001$ ).
- The mean combined reaction times in seconds were 291.95 (s.d.171.19) for 7-year-olds; 301.53 (s.d. 154.06) for 8-year-olds; 261.21(s.d. 147.3) for 9-year-olds; 250.93 (s.d. 177.97) for 10-year-olds; and 215.8 (s.d. 166.99) for 11-year-olds.
- Tamhane 2 post hoc tests showed that there were no significant differences between 7 - and 8-year-olds, 9 -and 10-year-olds, 9-and 11-year-olds, or 10-and 11-year-olds.
- But there were significant differences between 7 - and 9- year-olds, 7 - and 10-year-olds, 7 and 11-year-olds, 8- and 9-year-olds, 8- and 10-year-olds, and 8- and 11-year-olds, 9-and 10-year-olds.
- All significant differences were in the direction of older children having shorter reaction times.



# Effects of Age Group on Number Meaning Combined Reaction Time

- There was a highly significant effect of Age on Number Meaning Combined Reaction Time ( $F(4,2381) = 37.574$   $p = 0.001$ ).
- The mean scores were 103.93 (s.d. 78.46) for 7-year-olds; 87.18 (s.d. 60.56) for 8-year-olds; 70.23 (s.d. 47.97) for 9-year-olds; 61.48 (s.d. 38.34.) for 10-year-olds; and 59.11 (s.d. 38.56) for 11-year-olds.
- Tamhane 2 post hoc tests showed that all differences between ages were significant, except between 10- and 11-year-olds.
- All significant differences were in the direction of older children having shorter reaction times.



# Effects on Age Group on Number Relationships Combined Reaction Time

- There was a highly significant effect of Age on Number Relationships Combined Reaction Time ( $F(4,2381) = 14.946$ ;  $p = 0.001$ ).
- The mean scores were 690.78 (s.d. 422.62) for 7-year-olds; 786.57 (s.d. 455.76) for 8-year-olds; 874.75 (s.d. 433.82) for 9-year-olds; 931.18 (s.d. 472.88) for 10-year-olds; and 889.31 (s.d. 435.98) for 11-year-olds.
- Tamhane 2 post hoc tests showed that there were no significant differences between 9- and 10-year-olds; 9- and 11-year-olds; or 10- and 11-year-olds.
- But there were highly significant differences between 7- and 8-year-olds, 7- and 9-year-olds; 7- and 10-year-olds, 7 and 11-year-olds, 8- and 10-year-olds and 8- and 11-year-olds.
- Surprisingly, the significant differences were in the direction of older children having longer reaction times.



# Summary of reaction times findings

- Reaction times correlate with one another.
- Number Relationships Combined Reaction Time and Number Meaning Combined Reaction time correlate negatively; but other correlations are positive.
- Older children are faster than younger children at the Number Magnitude and Number Meaning tasks.
- But older children are slower than younger children at Number Relationships tasks.
- It is a somewhat puzzling result, but perhaps suggests that older and more able children are using more reflective, analytical strategies, that are more effective but slower.



# Overall Summary

- **Children improve with age on all measures**, except for an apparent slowing down on Number Relationships.
- The latter may reflect the development of slower but more accurate strategies: perhaps in response to teaching.
- There is variability in all the scores, including the Number Magnitude and Number Meaning scores.
- There are no ceiling effects, except perhaps for the oldest children with regard to Number Meaning.
- Thus, **Dynamo Assessment may prove a useful measure** for the study of individual and developmental differences in typically developing children as well as in those with mathematical difficulties.
- Further scope for Dyscalculia screening, assessment and intervention.



British Society for  
Research into  
Learning Mathematics [www.bsrlm.org.uk](http://www.bsrlm.org.uk)



[www.ox.ac.uk](http://www.ox.ac.uk)



[www.dynamomaths.co.uk](http://www.dynamomaths.co.uk)