G. Davis, C. Pearn, G. Price, and K. Smith, Connections between Counting and Reading, Proceedings of the International Symposium on Elementary Mathematics Teaching, August 24-29, 1997, Prague, The Czech Republic.

CONNECTIONS BETWEEN COUNTING AND READING

Gary Davis [1], Margeurite Merrifield [2] , Catherine Pearn [3],

Geraldine Price [1], Keith Smith [1]

[1] *School of Education, University of Southampton, U.K.*

[2] *Boroondara Park Primary School, Melbourne, Australia*

[3] *School of Education, La Trobe University, Australia*

Results from interviews designed to identify children with low counting and arithmetic skills have highlighted a link between children with mathematics and reading difficulties. We report on complementary studies in Australia and the United Kingdom in which young children were tested for counting and reading abilities, and suggest that unitizing plays a major role in both counting and reading.

Background

In the study of learning disabilities there has long been an observed connection between children's reading difficulties and their arithmetic problems (Ackermann et al, 1986; Geary, 1994; Kulak, 1993; Light and De Fries, 1995; Pearn, 1994). In the earliest years of schooling, children's counting strategies are a clear indicator of their development in arithmetic (Steffe et al, 1983, 1988; Wright, 1991). In particular, a child's ability to recognise and flexibly operate with composite units is recognised to be of critical importance in their arithmetic development (Steffe et al, 1983). On the other hand, readiness for reading is strongly linked to a child's phonemic awareness (Adams, 1995; Underwood and Batt, 1996).

To address difficulties exhibited by young children in their school mathematics a Mathematics Intervention program has been conducted at Boroondara Primary School, Melbourne, for the last three years (Pearn, & Hunting, 1995; Pearn, & Merrifield, 1996; 1995. See also Pearn, Merrifield & Mihalic, 1994a, 1994b), and for 2 years prior to that at Bulleen Primary School in Melbourne. The aim of the project was to identify and assist those children in Years 1 and 2 at risk of not coping with the mathematics curriculum as documented in the National Statement (Australian Education Council, 1991). The Mathematics Intervention Program adopted features of both Reading Recovery (Clay, 1987) and Mathematics Recovery (Wright, 1991) and was designed to offer children the chance to experience success in mathematics by developing basic number concepts .

Analysis of data from 1993-1995 highlighted a significant correlation between children participating in Mathematics Intervention and Reading Recovery programs. This program was continued in 1996, and a complementary study was carried out during 1996 at South Wonston Primary School in Hampshire, U.K.

Method

We tested 57 year 1 students age 5 - 6 years at Boroondara Park primary school in Melbourne, Australia. These students were tested for counting abilities, using the instrument described below, and for letter and word recognition, and reading ability. We also tested 29 students age 5 - 6 years at South Wonston primary school in Hampshire, U.K. to ascertain their counting abilities, their level of phonemic awareness, and their working memory (attention). Tests at South Wonston were administered independently. In both studies the class teacher completed a Pupil Rating Scale, described below.

Tests

Clinical interviews

Children were interviewed, using the Initial Clinical Assessment Procedure-Mathematics-Level AA, an instrument designed by three teachers (Pearn, Merrifield, Mihalic, & Hunting, 1994a, 1994b).

This instrument utilises tasks based on stages of the construction of the number sequence and their relationship to specific counting types. These 5 stages were developed in theoretical work by Steffe, Cobb, von Glaserfeld and Richards (1983) and documented by Wright (1991). The stages are:

1. Perceptual A child is limited to counting those items they can perceive- i.e. see, hear, touch.

2. Figurative Child counts from one when solving addition problems with screened collections. They appear to visualize the items and movements are important. (Often typified by the hand waving over hidden objects.)

3. Initial Number Sequence Children now count on to solve addition and missing addend problems with screened collections.

4. Implicitly Nested Number Sequence Children are able to focus on the collection of unit items as one thing, as well as the abstract unit items. They can count-on and count-down, choosing the most appropriate to solve problems. They generally count down to solve subtraction problems.

5. Explicitly Nested Number Sequence Children are simultaneously aware of 2 number sequences and can disembed smaller composite units from the composite unit that contains it, and then compare them. They understand that addition and subtraction are related in an inverse way and can use known facts such as doubles and sums which equal ten.

Teachers carrying out the interviews needed to be aware of strategies used by children when solving assessment tasks. When necessary the following prompts were given: "How did you work that out?" or "How did you do that?" The initial interview included tasks that ascertained the child's verbal counting skills by ones, twos, fives and tens, both backwards and forwards and used tasks based on the five counting stages developed by Steffe et al. (1983, 1988). For example:

"Can you start at 8 and count forwards from there?" (Stop at 25).

"Can you count backwards beginning at 43?" (Stop at 25).

Commonly used terms were also tested to determine the children's knowledge of the number sequence. For example,

"What number comes after 4?"

"What number comes before 15?"

There were five tasks based on the five counting stages. Interviewers were asked to observe and note strategies used by each child to solve these tasks. For example, the first task had six counters displayed and three hidden. The interviewer says to each student:

"There are six counters on the table. Can you count them?"

"Under this paper are three counters." (Lift paper briefly).

"How many counters do I have altogether?"

Reading tests

The reading tests utilised at Boroondara Park and South Wonston are somewhat different from each other, and are outlined below.

Boroondara Park: Reading tests formed the basis of identification for children needing to participate in a Reading Recovery program (Clay, 1987) and included: letter identification, word tests, running records, concepts about print, writing, hearing sounds in words (dictation).

South Wonston: These tests were based an a phonological assessment battery (details on request). There were essentially two types. The first ascertained speed in naming pictures and speed in naming digits. The second was a phonological test, designed to ascertain phonemic awareness, which included alliteration, rhyme, and spoonerisms tests.

Teacher questionnaires

The Pupil Rating Scale (Myklebust, 1981) was developed to identify children "who have good mental ability, good hearing and vision, and adequate emotional adjustment, who do not have overriding physical handicaps, but who still do not learn and achieve in school" (p. 6). The Scale consists of five behavioural characteristics: auditory comprehension and memory, spoken language, orientation, motor co-ordination, and personal-social behaviour

Each behavioural characteristics is divided into subscales. For example, "Auditory Comprehension and Memory" has four subscales: comprehending word meanings, following instructions, comprehending class discussions, retaining information. Teachers were asked to rate students for each subscales on a five point scale where a rating of 3 is average, ratings of 1 or 2 are below average and ratings of 4 or 5 are above average.

Star Counting

The Star Counting Test was designed "to measure a person's ability to activate and inhibit processes in working memory" (de Jong and Das-Smaal, 1995, p.81) where working memory is defined "a system for the temporary storage and processing of information and is used in a broad range of everyday cognitive tasks" (de Jong and das-Smaal, 1995, p. 80).

Each item in the Star Counting Test consists of a pattern of stars with arrows in between (see Figure 1). The child starts counting the stars from the given number. The upward and downward arrows indicate the direction (forward or backward, respectively) in which the stars should be counted. The original star Counting Test was modified for Year 1 students to take into account that some children only count backwards from ten. The cards increased in difficulty. Difficulty rating is dependent on the number of changes in the direction of counting, the size of the numbers used in counting and where the item appears in the actual test.

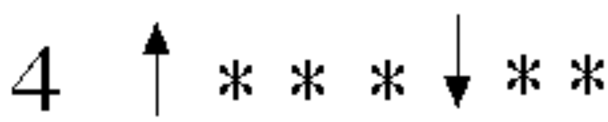

Figure 1 : An example of a simple star counting item (Correct answer is 5)

Results

Students scoring poorly

The scores on the four tests administered at South Wonston were normalised by dividing the test score for each student by the maximum test score for the class. The means and standard deviations for the normalised scores are shown in the table below. We define a student as scoring "poorly" on a test if the student is more than one standard deviation below the class average for the test. Notice that one student, TM, scored poorly on all four tests, CG scored poorly for "arithmetic", "attention", and "phonology", and students SK and TT scored poorly two of these cognitive variables. Notice that student NM scored poorly on the pupil rating scale but not on any of the cognitive tests.

	PUPIL RATING	ARITHMETIC	ATTENTION	PHONOLOGY
mean:	0.724	0.730	0.586	0.562
stdev:	0.187	0.184	0.328	0.339
mean - stdev:	0.536	0.546	0.258	0.223
mean + stdev:	0.911	0.915	0.914	0.901
	Students one STDEV below the mean:			
	AD	CG	AD	CG
	NM	SK	CS	BL
	TM	TM	CG	MJ
	TT	TT	ME	SB
		VJ	SK	TT
			TM	TM

Table 1: Students performing poorly, by test

For each student we calculated a measure of discrepancy between scores on the four tests as the square root of the sum of squares of all six differences of normalized scores. The discrepancies that are more than one standard deviation above the class mean are shown in Table 2 below.

NAME	PUPIL RATING	ARITHMETIC	ATTENTION	PHONOLOGY	DISCREPANCY
AD	0.483	0.745	0	0.575	1.107
ME	0.819	0.595	0.1	0.8	1.159
SK	0.75	0.49	0	0.675	1.169
BL	0.647	0.575	0.8	0	1.212

Table 2: Discrepancies one standard deviation above class average

These relatively high discrepancies highlight students with a stark difference between one or more scores. In three cases it is a very low attentional score that contributes substantially to the high discrepancy, whilst in another it is a very low phonological score. In these a very low level of functioning in one area is associated with moderate to good functioning in all others.

Correlations between variables

The correlations between the variables "pupil rating", "phonology", "arithmetic", and "attention" from the South Wonston data are shown in Table 1 below. Note that the figures are r^2, not r.

	Pupil rating	phonology	arithmetic	attention
Pupil rating	1			
phonology	0.51	1		
arithmetic	0.33	0.55	1	
attention	0.29	0.18	0.50	1

Table 1: Correlations between variables. Note: All figures are r^2, not r.

The three reading tests used at Boroondara Park- letter recognition, word recognition, and reading ability - were combined to give a score for a variable "reading". This variable correlated with "arithmetic" with $r^2 = 0.44$ ($p = 0.0001$), roughly consistent with the correlation at South Wonston between "phonology" and "arithmetic" ($r^2 = 0.55$, $p = 0.0001$).

There was a much higher correlation between the variable "arithmetic" and the sum of variables "phonology+attention", obtained from the South Wonston data:

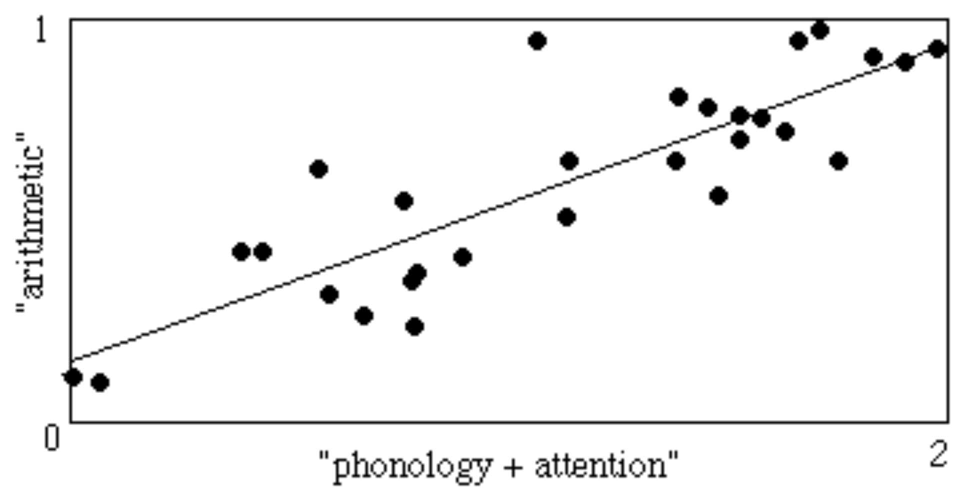

Figure 2: Regression line for "arithmetic" versus "phonology + attention"

$r^2 = 0.73$, $p = 0.0001$

This correlation says that about 3/4 (precisely, 73%) of the variation in students' arithmetic performance on the modified Initial Clinical Assessment Procedure -Mathematics-Level AA test can be accounted for by the average variation in phonological awareness and attention. "Attention" alone correlates 50% with "arithmetic" (i.e., $r^2 = 0.50$), whilst the correlation between "attention" and "phonology" is only 18% ($r^2 = 0.18$). This lends support to the following point of view: there is a common unitizing feature of the brain that deals with arithmetic units and phonological units. Arithmetic development, unlike phonological awareness, is also significantly connected to attention.

The ability to operate flexibly with phonemes can be viewed as a problem with knowing the roles of the constituent parts of a phoneme: the onset and the rhyme (Adams, 1995; Underwood and Batt, 1996). There are numerous constraints on the formation of onsets and rhymes in any language, but apparently almost no constraints on how these sub-units can be put together (Adams, 1995). It appears therefore that phonemic awareness is linked to the understanding of phonemes as composite units of an onset and a rhyme. A child's readiness for reading appears to be a function of the child's ability to be aware of these sub-units and to operate flexibly with them. On the other hand children's difficulties in counting are also strongly linked to their developing ability to operate flexibly with composite numerical units. We hypothesise that a common feature in the observed connection between reading and arithmetic difficulties that many young children have may be a in a common "unitizing" feature of the brain. Moreover, this hypothesised unitizing feature, in the case of arithmetic, seems to have some connection with attentional aspects of the brain's functioning.

References

Ackerman, P.T., Anhalt, J.M. and Dykman, R.A. (1986) Arithmetic automation failure in children with attention and reading disorders: Associations and sequela. Journal of Learning Disabilities, **19(4)**, 222-232.

Adams, M.J. (1995) Beginning to read. Thinking and Learning About Print. Cambridge, Mass.: MIT Press.

Australian Education Council (1990). *A national statement on mathematics for Australian schools*. Carlton: Curriculum Corporation.

Clay, M. M. (1987). Implementing Reading Recovery: Systematic adaptations to an educational innovation. *New Zealand Journal of Educational Studies*, **22(1)**, 35-58.

de Jong, P. F. & Das-Smaal, E. A. (1995). Attention and intelligence: The validity of the Star Counting Test. *Journal of Educational Psychology*. **87(1)**, 80-92

Geary, D.C. (1994) Children's mathematical development: research and practical applications. 2nd ed. Washington, DC: American Psychological Association.

Gibson, S. J., Doig, B. A., & Hunting, R. P. (1993). Inside their heads - the clinical interview in the classroom. In J. Mousley & M. Rice (Eds.), *Mathematics: Of primary importance*, pp. 30-35. Melbourne: Mathematical Association of Victoria.

Kulak, A.G. (1993). Parallels between math and reading disabilities: Common isssues and approaches. Journal of Learning Disabilities, **26(10)**, 666-673.

Light, J.G. and DeFries, J.C. (1995) Comorbidity of reading and mathematics disabilities: Genetic and enviromental etiologies. Journal of Learning Disabilities, **28(2)**, 96-106.

Myklebust, H. R. (1981). *The Pupil Rating Scale Revised: Screening for Learning Disabilities*. New York: Grune & Sutton.

Pearn, C. A. (1994). A connection between mathematics and language development in early mathematics. In G. Bell, R. Wright, N. Leeson & J. Geake (Eds.), Challenges in Mathematics Education: Constraints on Construction, Vol 2, pp. 463-470. Lismore, NSW: Southern Cross University.

Pearn, C. A. (1995). Mathematics intervention: Necessity or luxury? In R. P. Hunting, G. E. Fitzsimons, P. C. Clarkson, & A. J. Bishop (Eds.), *Regional Collaboration in Mathematics Education*, pp. 571-581. Clayton: Monash University.

Pearn, C. A., & Hunting, R. P. (1995). Mathematics Intervention: An Overview of the first two years. In B.

Atweh & S. Flavel (Eds.), *Proceedings of the Eighteenth Annual Conference of the Mathematics Education Research Group of Australasia*, pp. 446-452. Darwin: Northern Territory University.

Pearn, C. A. & Merrifield, M. (1995). Mathematics Intervention: Identification of students "at risk" and implications for classroom practice. In J. Wakefield & L. Verladi (Eds.), *Celebrating mathematics learning*, pp. 15-20. Melbourne: Mathematical Association of Victoria.

Pearn, C. A., & Merrifield, M. (1996). Strategies for classroom teachers: A lesson from Mathematics Intervention. In H. Forgasz, A. Jones, G. Leder, J. Lynch, K. Maguire, & C. Pearn (Eds.), *Mathematics: Making connections*. Melbourne: Mathematical Association of Victoria.

Pearn, C. A., Merrifield, M., & Mihalic, H. (1994). Intensive strategies with young children: A mathematics intervention program. In D. Rasmussen & K. Beesey (Eds.), *Mathematics without limits* (pp. 348-352). Melbourne: Mathematical Association of Victoria.

Pearn, C. A., Merrifield, M., Mihalic, H., & Hunting, R. P. (1994a). *Initial clinical assessment procedure, Mathematics - Level A A (Years 1 & 2)*. Bundoora: The Clinical Mathematics Laboratory, La Trobe University.

Steffe, L. P. , Von Glasersfeld, E., Richards, J. & Cobb, P. (1983). *Children's Counting Types: Philosophy, Theory, and Application*. New York: Praeger.

Steffe, L. P., Cobb, P. & Von Glasersfeld, E. (1988). *Construction of arithmetical meanings and strategies*. New York: Springer-Verlag.

Underwood, G. & Batt, V. (1996). Reading and Understanding. Oxford: Blackwell.

Wright, R. J. (1991). The role of counting in children's numerical development. The *Australian Journal of Early Childhood,* **16(2)**, 43-48.

Requests for further information, or original data sets, to:

Gary Davis,
School of Education,
University of Southampton,
SO17 1BJ,
U.K.

e-mail: gary@soton.ac.uk