Counting Rate, Naming Rate, Phonological Sensitivity, and Memory Span: Major Factors in Dyslexia

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Children with severe dyslexia were slower in counting from memory and naming alternating digits and letters than those with milder reading impairment. The children most disabled also had poorer phonological sensitivity, shorter digit spans, and lower Verbal IQs, but these variables accounted for no additional variance in prediction of scores on the Wide Range Achievement Test–Revised (R = 0.89).

For many years, investigators have been reporting memory deficits in children with reading disabilities (RD)/dyslexia (e.g., Bauer, 1977; Torgesen, 1985), and many types of experiments have been conducted to explore just where the deficit is (e.g., Ceci, 1984; Cohen, Netley, & Clarke, 1984; Siegel & Linder, 1984; Spring & Capps, 1974; Torgesen, Rashotte, Greenstein, Houck, & Portes, 1987). Other investigations have exposed a deficit in confrontational naming (Denckla & Rudel, 1976; Wolf, 1986; Wolf, Bally, & Morris, 1986), that is, a slower rate in naming stimuli such as letters, digits, and pictured objects. Spring and Perry (1986) were the first to relate sheer speed of articulation (counting from memory) with reading ability as well as memory span and naming rate.

Baddeley (1986) has convincingly demonstrated that memory span for verbal information is robustly related to the rate at which the to-be-learned information can be articulated. For example, if subjects are asked to recall five words that are one syllable in length, their performance is nearly perfect (90%), whereas their performance drops to about 50% correct if the words are five syllables in length (though matched for frequency and category). Underlying this relation ($r = 0.68$) is the fact that one-syllable words can be read at the rate of about 2.3 words per second, whereas five-syllable words can be read at only 1.3 words per second. Thus, encoding and rehearsal time would be usurped by longer words. We can infer, then, that persons who articulate more slowly than others would be at a disadvantage in rapidly paced memory tasks, as they would not have as much rehearsal time. Hulme, Thomson, Muir, and Laurence (1984) showed this to be the case in a developmental study involving children from 3 to 11 years and adults. Speech rate and memory span form a linear function at all age levels (see also Case, Kurland, & Goldberg, 1982).

Thus, the study by Spring and Perry (1986), showing that *individual differences* in rate of counting appear to limit memory span and reading ability, ties together several avenues of research. These investigators studied children from Grades 2 to 5 ($N = 30$) who were good and poor readers. Students who were good readers could count from memory at the rate of 5 digits per second compared with a rate of 4 digits per second for those who were poor readers. The good readers' rate of naming randomized digits was 2.0 digits per second, and the poor readers' rate was 1.1 per second. Performance on the two tasks was robustly correlated ($r = 0.67$, $p < .001$). Digit naming accounted for 61% of the variance in reading ability, but the bulk of this (41%) was also contributed by the counting task.

Torgesen et al. (1987) contrasted students with learning disabilities (LD) with normal versus poor digit spans (less than 5 forward). Like Spring and Perry (1986), these investigators found digit naming speed to be correlated with digit span ($r = 0.55$, $p < .01$). Torgesen and his colleagues believe that a major reason for the reading difficulty of the subjects with short spans is that they cannot maintain phonetically coded material in working memory long enough to achieve blending. It is difficult to understand, however, why the limit in working memory should hamper the learning of one- and two-syllable words, which predominate in beginning reading materials.

Thus, the demonstration that a large fraction of children with RD have impaired phonological awareness suggests another, and perhaps more basic, dysfunction (see Stanovich, 1986; Vellutino, 1987; and Wagner & Torgesen, 1987, for reviews). Most simply put, children with RD seem less able to appreciate that articulated sounds fall into logical groupings. They falter in recognizing and generating rhymes and alliterations (Ackerman, Anhalt, & Dykman, 1986; Ackerman, Anhalt, Dykman, & Holcomb, 1986; Bradley & Bryant, 1983). Also, young children with RD are less able to segment words into sounds—even into syllables, but especially into phonemes (Liberman & Shankweiler, 1985; Mann, 1986).

Baddeley (1986) theorizes, however, that a slow articulation rate leads to impaired functioning of the articulatory loop and that this dysfunction may be at the root of phonological dyslexia as well as working memory impairment. Why should this be so? The answer may lie in the way children are taught phonetic decoding. As Baddeley points out, consonants are virtually impossible to pronounce in isolation. Thus, many reading teachers ask their students to add a redundant *uh* sound to each consonant. In this manner, even the short word *mad* becomes *muh, a, duh*. Now, how could anyone hear *mad* in that, especially if it is slowly articulated?

In a group of children with RD, we obtained measures of articulation rate (counting from memory), continuous naming speed, phonological sensitivity, and digit span. Here we shall explore further the interrelatedness of these four seemingly underlying processes and ascertain how much each contributes to the prediction of word decoding, discourse reading, reading comprehension, and spelling.

METHOD

Subjects. Subjects were 20 children with RD, aged 9 to 12 years, who participated in a summer tutoring program. To be selected, the children had to have recent psychoeducational test results documenting impaired reading/spelling for age and IQ. More specifically, we required that the Wechsler Intelligence Scale for Children–Revised (WISC-R) (Wechsler, 1974) Full Scale IQ be at least 80, that the mean of the revised Wide Range Achievement Test (WRAT-R) (Jastak & Jastak, 1984) reading and spelling standard scores be 90 or lower, and that this mean score be at least 10 points lower than the Full Scale IQ. The group was composed of 13 boys and 7 girls, all Caucasian except one black boy. Mean age was 123 months (± 10). Mean Full Scale IQ was 97.5 (± 9.1). Mean Verbal IQ was 96.6 (± 11.2) and mean Performance IQ was 99.0 (± 9.8). The sexes did not differ significantly on age, reading, spelling, or IQ measures.

Tests. The complete WRAT-R was readministered to all subjects in addition to the revised Gray Oral Reading Test (GORT-R) (Wiederholt & Bryant, 1986); the Decoding Skills Test, Parts I and II (DST) (Richardson & DiBenedetto, 1985); and the Boder Test (Boder & Jarrico, 1982), which was used to classify children as dysphonetic or not. Measures of hypothesized underlying processes obtained were (a) time to count from 1 to 10 five times in a row (counting speed); (b) time to name 50 alternating digits and letters, arranged in 10 rows of five stimuli, similar to the Rapid Alternating Stimulus Task (RAS) (Wolf, 1986); (c) the Bradley (1984) Test of Phonological Sensitivity to rhyme and alliteration; and (d) auditory digit span, forward and backward (the highest span correctly repeated).

For those unfamiliar with all the tests, the GORT-R provides mean standard scores for comprehension and oral reading. The first part of the DST is a word recognition task and the second part assesses ability to decode 30 monosyllabic and 30 polysyllabic nonsense words (Richardson & DiBenedetto, 1985). Bradley's test has eight items in each of three conditions (two rhyming and one alliteration). The child hears four one-syllable words and is asked to identify the one that does not belong because of the way it sounds (e.g., *dug, rug,* **sun**, *tub; bud, bun, bus,* ***rug***).

RESULTS

The mean WRAT-R reading and spelling standard scores (72.7 and 74.6) were 25 points below mean Full Scale IQ. The mean GORT-R passage reading standard score of 4.9 was well below the mean for comprehension (7.0). The DST mean performance was at grade level 3.3. The various measures of reading were very highly intercorrelated (above .90) except for more modest associations (from .71 to .82) with the comprehension scores from the GORT-R.

The subjects counted at a mean rate of 3.8 digits per second and named digits and letters at 1.1 per second, rates very near those obtained by Spring and Perry (1986) in their poor reader group. On the Bradley Test of Phonological Sensitivity, the children's percentage correct averaged 74%, which is well below the 88% correct found in the normative sample for 9-year-old children. The mean forward digit span (5.1) was somewhat lower than would be projected from Baddeley's (1986) rule (i.e., span = 1.5 x digit per second naming rate). The mean backward span was only 3.4. The sexes did not differ on any of these measures.

As for intercorrelations of the hypothesized underlying factors, counting rate was most strongly associated with phonological sensitivity (-0.71), while the RAS naming rate was most strongly associated with forward digit span (-0.63). Because the RAS times were markedly skewed, we did reciprocal transformations of both time measures and recomputed the correlations (see also Walsh, Price, & Gillingham, 1988). These figures were not appreciably different from those computed with raw scores. Counting times and RAS naming times were not significantly related in raw score or transformed score units. However, the exclusion of a major outlier on the RAS (rate = 0.4 stimuli per second) results in a correlation of 0.66, for he counted from memory rapidly—4.2 digits per second. None of the underlying variables was significantly related to age. Counting and naming rates and forward digit span were moderately correlated with Verbal IQ (from .56 to .66).

The next series of analyses used stepwise regression to predict word list reading, passage reading, comprehension, and spelling (raw scores) from the hypothesized underlying variables. With F set to 4.0, we first forced age. Then counting (articulation) rate, naming rate, phonological sensitivity score, digit span forward, digit span backward, and Verbal IQ were allowed to enter in any order (see Table 1). WRAT-R reading and spelling scores were best predicted by the same set: age, counting rate, and naming rate. Because phonological sensitivity was strongly related to counting rate, it added nothing further to the multiple Rs. And because digit span forward was robustly related to naming rate, it did not enter into the final regression equations. Age was not significantly correlated with GORT-R comprehension; hence Verbal IQ entered as Step 1 in that analysis.

DISCUSSION

Although this study did not involve enough children, a large enough age range, or enough tasks to pin down definitively the major subprocesses that underlie specific reading disability (dyslexia), it does suggest that the most severely affected children have slow articulation and/or continuous naming rates for sequential alphanumeric stimuli. While most of the readers with severe RD also had impaired phonological sensitivity and immediate memory spans, the phonological impairment was linked robustly to slow articulation (i.e., counting), while impaired memory span was associated more strongly with slow confrontational naming of alternating letters and digits (RAS). Thus, phonological sensitivity and digit span added no additional variance in explaining word decoding and spelling.

We did not find the strong link between counting and naming reported by Spring and Perry (1986), but they studied both normal and poor readers and used digits only for naming. We elected to use the RAS task because Wolf (1986) had shown RAS rates to be more robustly related to reading than digit naming or letter naming rates in older elementary school children. Note also that the correlation between counting and naming rates rose to 0.66 ($p < .01$) when we excluded the most extreme RAS outlier. Still, Morris (1987) reported a dissocia-

TABLE 1
Stepwise Regression to Predict Performance Levels in Children with Reading Disability

Dependent variables	Step	Predictors	R	zero rs
WRAT-R Reading	1.	Age	.49	.49
	2.	RAS Naming	.81	.72*
	3.	Counting	.89**	.62*
WRAT-R Spelling	1.	Age	.49	.49
	2.	Counting	.81	.70*
	3.	RAS Naming	.90**	.66*
GORT-R Discourse	1.	Age	.48	.48
	2.	Verbal IQ	.76**	.68*
GORT-R Comprehension	1.	Verbal IQ	.77	.77*
	2.	Counting	.86**	.77*

WRAT-R = Wide Range Achievement Test-Revised; GORT-R = Gray Oral Reading Test-Revised; RAS = Rapid Alternating Stimulus Task.
*$p < .001$; **$p < .01$.

tion of counting and digit naming rates in patients with Alzheimer's disease. These patients named digits as fast as age-matched controls but counted from memory very slowly.

While continuous naming has been well studied by reading researchers in this country (see especially Bowers, Steffy, & Tate, 1988; Denckla & Rudel, 1976; Walsh et al., 1988; Wolf, 1986; Wolf et al., 1986), articulation rate has not. It is important in the light of Baddeley's (1986) work, Spring and Perry's (1986) study, and the findings reported here to try to understand more about speech rates for words of varying length or repeated syllable sequences (see Wolff, Cohen, & Drake, 1984).

The available evidence suggests that students with RD are prone to articulate *sequences* more slowly than nondisabled students, perhaps because to speak faster would lead to a "tangled tongue." By inference, their inner speech is slower as well, meaning that in a given period of time the slow speaking child could not rehearse a list of new sight or spelling words, say, as many times as a faster speaking child. Likewise, the slow speaking child would have more trouble sounding out and blending polysyllabic words and comprehending what he or she has read. And, Baddeley's (1986) explanation of the link with decoding difficulty, as given in the introduction, seems reasonable even in the case of short words. An intriguing question for future research is whether slow speaking children with RD can be taught to articulate sequences more rapidly, and, if so, whether this generalizes and they then become more able learners.

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