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ABSTRACT

A study investigated whether a visual selective attention deficit with its presumed basis in slow visual processing referred to the same phonological recoding deficit, or whether they were two independent sources of reading disability. Subjects were children aged 7 to 15 referred to a university clinic (the Waterloo Child Assessment Project--WATCAP) by parents or community agencies for assessment of neuropsychological and attentional functions. Each child was given an extensive battery of tests, including the WISC-R, Woodcock-Johnson Psychoeducational Battery Tests of Achievement, most of the Reitan neuropsychological battery, a battery of RT measures of attention and distractibility, and the Lincoln-Oseretzky tests of motor skills, as well as tests of color and digit naming speed and auditory memory for sentences. Parents completed developmental histories, the Peterson-Quay Behavior Problem Checklist and Connors' Parent Rating Scales. Results showed that naming speed was a significant contributor to reading achievement, but gave no support to a selective attention deficit contribution to reading disability. As predicted, naming speed contributed more variance to the word attack subtest than to the other reading subskills. (HOD)

A Comparison of the Contributions of Phonological Recoding and Selective Attention Deficits to Reading Disability

P. G. Bowers, R. S. Steffy, W. Corning & L. Butson

A comparison of the contributions of phonological recoding and selective attention deficits to reading disability

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Much research has attempted to uncover the bases for "unexpected" reading failure, i.e., severe deficits in reading ability despite average intellectual and sensory ability and cultural opportunity. And during the last decade, a conviction has grown among many researchers that a deficit in the verbal coding process characterizes most dyslexic children (Vellutino, et al., 1975). Jorm (1983) and Jorm & Share (1983) argue that it is the sounds of the language or phonological codes that are poorly utilized in information processing, such that there may be initially poor encoding of the sound or pronunciation of the "name" or "label" of an object (or symbol) leading to difficulty or slowness in retrieving the "name" from long term memory, i.e., recoding it verbally from visual stimuli. Such a deficit will interfere in many ways with various reading tasks, from blending sounds and decoding words to comprehending stories.

There is some evidence that children with phonological recoding problems are still able to utilize semantic aspects of language quite well. Their memory for meaningful material is more similar to normal readers than is their memory for material learned by rote, where the sounds must be kept in mind without recourse to meaning. Thus they may be able to repeat the "gist" of sentences given to them but forget the precise ordering of the words (Waller, 1976). Research from Cohen's (1982) lab supports a phonological deficit interpretation of the short term memory problems of poor readers. Shankweiler et al's (1979) findings that young poor readers do not show the typical impairment in recall of rhyming compared to non-rhyming words underlies the poor reader's specific difficulty in using sounds to aid recall. Thus in his review of the area, Jorm (1983) concludes that while dyslexic children have adequate longterm memory for non verbal material and for semantic aspects of verbal material, they have difficulty in the storage and retrieval of phonological aspects of verbal material in long term memory.

That the phonological recoding difficulty is a pervasive one is indicated by findings replicated many times that dyslexics are slower in naming visually presented stimuli, even when the stimuli are not alphabetic in nature. Thus color patches, familiar objects and digits as well as letters are named more slowly (Denkla & Rudel, 1976; Spring & Capps, 1974; Ellis, 1981). (Various experiments have demonstrated that alternative explanations for the slow naming speed, such as articulation reaction time (Ellis, 1981) or the sequential nature of typical naming tests (Stanovich et al., 1983) do not fully account for the effect.)[1]

Slowness in learning the names of letters is a good predictor of early reading failure (Jansky & de Hirsch, 1972). Perhaps good prospective developmental studies would show that slow learning of the arbitrary "name" we give to objects or colors lies behind the slower "naming" of these items even when by age 7 the names are very well known by the child and he makes no errors. These now meaningful names of things can be used in comprehending oral messages and in reasoning, and the onlooker might never know that the phonological representation of an object takes a few milliseconds longer to retrieve. Retrieving the sounds of letters and syllables quickly, however, is necessary to the automatic information processing vital to skilled reading (LaBerge and Samuels, 1974). Jorm & Share (1983) propose a model of learning to read in which this slow speed of retrieval plays a central role. Slower retrieval impairs blending of sounds and word recognition. In turn, slow word decoding leads to fewer repetitions of whole words so that newly encountered words have less opportunity to become overlearned and automatized. Finally, comprehension is affected by the degree of automaticity of these lower-level reading skills (La Berge & Samuels 1974, Stanovich, 1980; 1982b).

While the hypothesis that a "verbal code" deficit is involved in dyslexia has gained ascendence in recent years, there continues to be an alternative or supplementary hypothesis that a sizeable portion of dyslexic children have a visual selective attention deficit. While reading disabled children may not be more prone to distraction by irrelevant extrinsic stimuli than normal readers (Douglas & Peters, 1979), there is some evidence to suggest that temporarily irrelevant visual stimuli <u>within</u> a task impairs performance (Ross, 1976; Willows, 1974, 1978; Douglas & Peters, 1979; McIntyre et al., 1978).

Thus, reading disabled children may be no more distracted by others talking in the room than normal readers, but the other material on a page of print, perhaps the pictures (Willows, 1978) or perhaps the words on other lines than the "target" word (Willows, 1974), may serve as distractors. They may find it difficult to quickly focus on just the relevant bit of information and isolate it from momentarily "irrelevant" information in the same field of vision. Such a deficit might lead to the confusion between letters often reported, and to incomplete analysis of words since systematic focusing on relevant aspects of stimuli is necessary for these performances. One traditional measure of selective attention has been the Span of Apprehension (Estes, 1965). The simple condition of "no distractors" (Span A) requires simple discrimination of T or F flashed briefly on a screen. In contrast, Span D places the T or F in a field of 9 competing "noise" letters. The subject must detect only the T or F, so memory load is no greater than in Span A. McIntyre et al (1978) found that reading disabled children were impaired on Span D while they were not on Span A, supporting the visual selective attention deficit hypothesis. However, confusion of visually similar symbols did not account for their results. Instead, Mazer et al. (1983) and Bryant et al. (1983) suggested slow visual processing as a mechanism for poor Span D performance.

Does the visual selective attention deficit with its presumed basis in slow visual processing refer to the same phonological recoding deficit, or are they two independent sources of reading disability? Slow naming and therefore identification of a visual stimulus might be confusable with a slow specifically visual process. The present study is designed to evaluate the degree of independence of these two hypothesized sources of reading impairment, and their relative contributions to differing reading subskills.

Method

Subjects were school-aged children from 7 to 15 who were referred to a university clinic (the Waterloo Child Assessment Project [WATCAP]) by parents or community agencies for assessment of neuropsychological and attentional functions. While educational and attentional problems were the most common complaint, behavioral and social-emotional difficulties were cited as well in a sizeable minority of WATCAP clients.

Each child was given an extensive battery of tests, including the WISC-R, Woodcock-Johnson Psychoeducational Battery Tests of Achievement, (Woodcock, 1981) most of the Reitan neuropsychological battery, a battery of RT measures of attention and distractibility, the Lincoln-Oseretzky tests of motor skills as well as tests of color and digit naming speed and auditory memory for sentences. Parents filled out developmental histories, the Peterson-Quay Behavior Problem Checklist (Quay & Peterson, 1979) and Conners' Parent Rating Scales (Goyette et al., 1978). The testing was spread usually over 2-3 days. For purposes of this report only the theoretically pertinent measures will be described in more detail.

The present study is based on all those referred to the clinic whose WISC-R Full Scale, Verbal and Performance IQ were at least 80 and who had been administered the variables of interest. There were 39 such subjects[2], 31 boys and 8 girls, with a mean age of 10.7 years (SD=2.4). Mean Full Scale WISC-R IQ for this sample is 108 (SD=13) and Verbal and Performance IQ's do not differ (107.5 and 107.8 respectively). Of some interest is the factor score means for this sample. Factor analyses of the WISC-R reliably obtain 3 factors, Verbal Comprehension (V.C.) (composed of Information, Vocabulary, Comprehension and Similarities), Perceptual Organization (P.O.) (Block Design, Picture Completion Picture Arrangement, Object Assembly and Mazes) and a minor 3rd factor, Freedom From Distractibility (F.D.) (Arithmetic, Digit Span and Coding). Children with diagnoses ranging from reading disability to hyperactivity to emotional problems are reported to have low FD factor scores. Consistent with this literature, our clinic sample had mean VC and PO scores of 11.6 (SD=2.3) and 11.6 (SD=1.9) respectively but a mean FD score of 9.0 (SD=2.4). Predictors of FD scores within this sample are discussed elsewhere (Bowers et al. 1984).

Measures

Two hypotheses regarding the nature of the deficits associated with poor reading achievement were addressed.

(a) The phonological recoding deficit hypothesis was represented by two naming speed tests using procedures described by Spring and Capps (1974).

Digit Naming Speed and Color Naming Speed were assessed by having the child name as quickly as possible (1) a string of 50 one syllable digits printed in a row (8 digits repeated 6 times in random order) and (2) a display of 30 color patches of seven common colors repeated randomly in five rows of six colors. Each naming test was given twice. The child's score was the average number of colors and digits named per second across the two trials.

(b) The selective attention deficit hypothesis was evaluated by the Span of Apprehension Test (Form D) (Estes, 1965). The child sits before a screen on which is desplayed for 1/20 of a second the target letter T or F either alone or surrounded by varying numbers of distractor letters. The child is told that on each trial there will be either a T or an F and he is to identify which of these 2 letters is present, ignoring any other letters which may appear. The experimenter presents a new trial after the child identifies the previous target. There are 160 trials, with groups of differing "spans" randomly presented. The number of errors on Span D (with 9 distracting letters) was considered the best test of the selective attention deficit hypothesis, measuring how well the child selects the target from among the distractors. Variance due to memory and sustained attention are minimized on this task.

Control Tasks

(a) In order to assess whether it is the selective attention deficit per se which contributes to reading disability or rather the inadequate processing of the visual information even without a need for selectivity, the number of errors on Span A (no distractors) was assessed.

(b) The literature suggests that reading disability is not a function of distractibility by events external to the task.

Since such distractibility is predicted by neither a phonological recoding nor a selective attention deficit hypothesis, positive findings on such a measure would weaken the interpretation of any findings with respect to the major hypotheses. Therefore we constructed an impairment index measuring the effect of distracting stimuli imposed on a reaction time test. Our measure of distractibility is the difference between reaction time (RT) latency during trials when a "probe" stimulus (a bright light and extraneous visual noise stimuli in the fixation field) is flashed very briefly at the beginning of the trial vs. RT latency when no such distractors occur. The child's task at the beginning of each trial is to press a telegraph key and to lift his finger as soon as possible after the lift signal (a buzzer) sounds. He is told to ignore occasionally occurring visual stimulation. There is a varied waiting period on both probed and standard trials of 1, 3, 7 or 9 seconds. The measure of distractibility then is the degree to which RT latency across all waiting periods is impaired by the distracting stimuli.

Reading Ability

The global construct "reading ability" needs to be delineated more finely in order to ascertain the nature of underlying deficits. While component skills in reading are usually highly correlated (Woodcock, 1981) several studies have suggested that while dyslexic children are below average in sight word decoding and reading comprehension, they are particularly disadvantaged in applying letter-sound correspondences or phonetic rules to decode unfamiliar words (Ellis, 1981; Kochnower et al., 1983). The recently standardized Reading Cluster of the Woodcock-Johnson Tests of Psychoeducational Achievement (Woodcock, 1981) enables us to look at both determinants of overall reading skill and of the major reading subskills. The Word Attack subtest requires the child to pronounce pseudo words, e.g., "nam". The Letter-Word Identification requires identification of actual single words of varying dificulty, i.e., "table". Passage Comprehension requires the child to read silently passages of differing complexity and supply orally the missing word, which can be done correctly only on the basis of having understood the general meaning of the passage.

Intellectual Ability

In this study, the IQ scores on the WISC-R are used not only in the selection of subjects, but also as a control variable. Even within a normal IQ sample, general ability is a potent predictor of reading; we are interested in learning the correlates of reading after accounting for the influence of general ability. The 5 subtests of the WISC-R which are most highly "g-loaded", that is, load highest on the factor common to all the subtests, are Information, Comprehension, Similarities, Vocabulary and Block Design. The major WISC-R factor of Verbal Comprehension overlaps considerably with the "g" factor. Therefore, controlling in our analysis for the g-factor ensures not only that general ability is not confounded in the results, but that variability in the understanding and use of oral language does not account for any findings. Since the phonological recoding deficit hypothesis suggests that semantic use of language can be intact while phonological aspects are deficient, controlling for oral language comprehension will provide for a stronger test of the phonological deficit hypothesis.

Since of course age contributes to both reading skill and scores on the variables of interest, it too is controlled statistically.

Data were analyzed by means of partial correlations and hierarchical regression analyses.

Hypotheses:

1. After age and WISC-R g factor variance is removed, phonological recoding as measured by naming speed, and selective attention as assessed by Span of Apprehension D, contribute independent variance to reading achievement.

2. Since stimuli external to a task is predicted by neither hypothesis to affect poor readers more than good readers, there should be no relationship between reading skill and an index of distraction on an RT task.

3. Among the reading subskills, "Word Attack" is most affected by the naming speed variable, since application of letter-sound correspondences are apt to be most directly affected by the speed of naming letters or letter sounds, another instance of phonological recoding from visual stimuli.

Results

The means and SD of the sample on the variables under discussion and the intercorrelations of variables after controlling for age, are listed in Table 1. The mean reading achievement age is two years below the mean chronological age of the sample. However, there is a wide range of achievement, with 33% of children 2 or more years below their expected reading age based on Woodcock-Johnson U.S. norms, and another 20% 1 year or more below. However, 28% of the sample is 1 or more years above expected reading age, with 18% scoring within 1 year of that expected for their chronological age.

The test of the major hypothesis is a hierarchical regression analysis predicting reading cluster scores in which age and g factor scores are entered first as control variables, and then Digit and Color naming speed and Span D are entered to determine their independent contribution to reading. Several analyses were done, reversing the order of ntry, to estimate the relative contribution of each variable. Table II present the multiple R and the amount of new independent variance contributed to the prediction of reading achievement by each variable in turn.

The results of these analyses suggest that in this sample, naming speed is a very significant contributor to reading achievement. While both naming variables contribute significant variance independent of age and intelligence, the variance contributed by color naming speed is not independent of digit naming speed, and the latter is the larger contributor. In contrast, Span D, showed only a tendency ($p<.07$) toward an independent contribution, and even this small variance was redundant with that contributed by the naming speed variables.

The simple Span A variable requiring quick visual processing but no selective attention contributed a nonsignificant 3% of variance to reading. With variance contributed by Span A removed, the contribution to reading by Span D no longer even approached significance. In sum, no support is given to a selective attention deficit contribution to reading disability. Table II also shows that as predicted, the degree to which performance on a RT measure is impaired by an external distractor is unrelated to reading.

Table III indicates that naming speed is a significant predictor of performance on each of the reading subtests, both when only the contributions of age and intelligence were controlled and when, in addition, the contribution of selective attention was controlled as well. Selective attention, as measured by Span D does contribute some independent variance however to Word Attack. Whether this variance was specific to the selectivity of attention or to quick visual processing with no selection demands was tested by finding what the contribution of Span A was to Word Attack, and whether Span D contributed independently of Span A. After controlling for age and intelligence, Span A contributed significant variance (8%, $p<.05$) to Word attack, and Span D contributed an additional 7% ($p<.05$) of variance. When Digit Naming Speed entered the equation prior to Span A, Span A no longer contributed significant additional variance. There was a tendency for Span D to continue to contribute (4%, $p<.06$).

As predicted, naming speed contributed more variance to the Word Attack subtest than to the other reading subskills. In fact, in this sample, naming speed contributes more to the decoding of nonsense words than does age or intelligence. Color naming speed is a strong predictor of Word Attack scores when entered prior to digit naming speed, suggesting that the naming speed contribution to reading is not limited to the naming of symbols but is a more general process. Nevertheless, the naming of digits has additional predictive power.

Discussion

Naming Speed or speed of recoding verbally a visual stimulus has proven to be a strong independent predictor of reading achievement, in contrast to the general lack of independent contribution to reading of a specifically selective attention deficit. The results of the present study support the conclusions of Ellis (1981) who failed to find deficits in visual analysis among poor readers, while confirming the presence of verbal code deficits. Similarly supported is the finding of Cermak (1983) that LD children perform name match tasks more slowly than physical match tasks, in contrast to controls who performed both tasks equally quickly. For only the Word Attack subtest was there a tendency for an independent selective visual attention contribution. Overall, the results support the phonological recoding deficit version of the verbal code weakness hypothesis. The naming speed contribution to reading was independent of not only general intelligence but verbal comprehension ability. Children well able to use the semantic aspects of language in reasoning and other tasks nevertheless might lag behind their peers in the speed of recoding visual stimuli into the appropriate phonological code. This is a general deficit, not specific to recoding written words, since even recoding a color patch occurs more slowly. But since reading is often accomplished by phonological recoding of the visual stimulus, the slowness of phonological recoding has a major impact on reading achievement. The model proposed by Jorm & Share (1983) is supported by these findings. Slow retrieval from long term memory of the sound of letters or syllables, may hamper the decoding of words, especially unfamiliar ones. The special impact of such slow retrieval of phonological codes is seen in the marked contribution of naming speed to decoding nonsense words. While this is the most direct effect of slow naming, its ramifications also affect identification of words and passage comprehension.

While the reasons for the lack of replication of the work of McIntyre and his colleagues with respect to the Span of Apprehension are not clear, differences in subject selection and types of statistical analyses may account for the disparate results. The present study used Span of Apprehension measures to predict reading scores within a heterogeneous clinic sample, whereas McIntyre and colleagues contrasted mean Span scores of normal and learning disabled children. The work of Bryant et al. (1983) suggesting that learning disabled boys pick up visual information more slowly continues to be an interesting possibility, but little support for a specifically visual processing slowness was gained in this study. Instead, if slower name retrieval can cause occasional errors in correct identification of a single target, the contribution of errors in Span A (target only condition) to Word Attack performance can be understood. However, the present research design was not sensitive to the possible presence of a small subtype of reading disability with specifically visual analysis difficulties.

Further research is clearly needed to clarify the nature of the naming speed variable. Research with the present sample (Bowers et al., 1984) indicated that naming speed is a highly significant predictor of FD factor scores. The present study has shown its relationship to reading achievement. Determining more precisely the mechanisms accounting for naming speed's effects may help to clarify the phonological deficit hypothesis of reading disability.

Footnotes

[1]Failure to replicate a relationship between reading achievement and speed of naming of non-alphabetic stimuli has occurred in a few samples of less skilled readers who were not severely disabled (Perfetti et al., 1978; Stanovich, 1981).

[2]Two subjects were inadvertently not given the color naming speed test, but were included since they did have digit naming speed data.

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TABLE I

Mean, SD, and Partial Correlations controlling for age for all variables.

	Variables	N	Mean	SD	1	2	3	4	5	6	7	8	9
1.	Reading Cluster Age Equivalent	39	8.6	7.2-12.2	X	.92***	.88***	.90***	.62***	.32***	-.40**	-.31***	.04
2.	L-W Identification (standard score)	39	163	13.1		X	.73***	.75***	.58***	.29***	-.31*	-.20	.10
3.	Word Attack (Standard score)	39	162	7.6			X	.68***	.72***	.52***	-.48***	-.38**	.15
4.	Passage Compreh-ension (standard score)	39	162	10.4				X	.44***	.11	-.34*	-.27*	-.11
5.	Digit Naming Speed	39	1.7	.5					X	.72***	-.27*	-.25	-.02
6.	Color Naming Speed	37	1.1	.3						X	-.22	-.29*	.02
7.	Span D Errors	39	9.0	4.2							X	.45**	-.05
8.	Span A Errors	39	.9	1.2								X	-.02
9.	Distractor RT latency	39	24ms.	63 ms.									X

* $p \leq .05$

** $p \leq .01$

*** $p \leq .001$

TABLE II

Multiple Regression Analyses predicting Reading Cluster

Variable	Order of Entry	R	R^2 Increase	Order of Entry	R	R^2 Increase	Order of Entry	R	R^2 Increase
Age	1	.66	.43**						
WISC-R g factor	2	.75	.14**						
Digit Naming Speed	3	.85	.16***	5	.87	.10**			
Color Naming Speed	4	.86	.01	4	.80	.04⊗	3	.79	.06*
Span D Errors	5	.87	.02	3	.78	.04⊗	4	.80	.02
Span A Errors	3	.77	.03						
Span D Errors	4	.78	.02						
Distractor RT latency	3	.75	.00						

⊗ $p < .1$

* $p < .05$

** $p < .01$

*** $p < .001$

TABLE III

Multiple Regression Analyses Predicting Reading Subtests

Criterion	Predictor	Order of Entry	R	R^2 Increase	Order of Entry	R	R^2 Increase	Order of Entry	R	R^2 Increase
L-W Identification	age	1	.70	.49***						
	WISC-R g	2	.80	.14***						
	Digit Naming Speed	3	.87	.12***	5	.87	.08**			
	Color Naming Speed	4	.87	.00	4	.82	.03 @	3	.82	.04 @
	Span D Errors	5	.87	.00	3	.80	.01	4	.82	.00
Word Attack	age	1	.45	.21**						
	WISC-R g	2	.52	.07 @						
	Digit Naming Speed	3	.80	.36***	5	.83	.14***			
	Color Naming Speed	4	.80	.00	4	.74	.15**	3	.70	.21***
	Span D Errors	5	.83	.05*	3	.64	.13**	4	.74	.07*
	Span A Errors	3	.60	.08*	4	.81	.02			
	Span D Errors	4	.65	.07*	5	.83	.04 @			
	Digit Naming Speed	5	.83	.27***	3	.80	.36***			
Passage Comprehension	age	1	.61	.37***						
	WISC-R g	2	.72	.14**						
	Digit Naming Speed	3	.77	.08*	5	.80	.09**			
	Color Naming Speed	4	.79		4	.74	.00	3	.72	.01
	Span D Errors	5	.80		3	.74	.03	4	.74	.02

p < .1
* p < .05
** p < .01
*** p < .0001