Retrieval and Evaluation of Symbolic Information in Dyslexia

Jerome Kagan

Harvard University
Cambridge Massachusetts

Michael J. Moore

Boston College
Boston Massachusetts

The research to be described in this report was conducted in two phases. The first, which was more exploratory than the second, focussed on memory performance and perception. The second phase attempted to explore systematically a hypothesis originating in the first phase suggesting that reading disabled children have difficulty processing linguistically presented propositions. This work represents a next step in the continuing search for the defining qualities of reading disabled subjects. It is viewed as formative rather than definitive—steps toward the solution of an intriguing and significant developmental problem.

Subjects

Thirty-five reading disabled children and thirty-five normal readers (all were boys) participated in the first phase of this study. The reading disabled subjects were reading at least two years below grade level at a mean of the second grade, based on a standardized test of reading skill. However, the subjects had IQ scores within the normal range (90 to 120). The reading disabled children were located after extensive search of the school systems within the greater Boston area, and all had been diagnosed as reading disabled by their schools. However a reading disabled boy was included in our sample only if he met the criteria outlined below. Control subjects, who were reading at or above grade level, were matched with the reading disabled boys for age (within one year), ordinal position, and education and occupation of the parents. All subjects came from Caucasian, middle-class families, had normal vision and hearing, and had

This research was supported by a grant from the Lilly Endowment, Inc. We thank Michelle Shal and Susan Grant for their participation in this work.

no history of physical problems. The reading disabled children ranged in age from 8.0 to 12.4 years (mean = 10.4 years); the controls ranged from 8.0 to 12.8 years (mean = 10.3 years). Subjects were tested 12 to 14 times at Harvard University over a two-year period by the same two women.

Initially, all children were administered the Gilmore Oral Reading Test to evaluate reading ability and the Wechsler Intelligence Scale for Children-Revised, to obtain each child's IQ. The child's hearing was measured with the Zenith 112–A audiometer and vision with the Good-Lite Illiterate E Chart. Parents were asked to complete questionnaires to provide information about their child's medical history and experience in school as well as a description of family structure and parental social class.

We shall now present the three major conclusions resulting from this research and describe the methods appropriate to those conclusions as the latter are presented.

Perceptual Functioning

Subjects were asked to name the letters b, d, p, g, printed in lower case on a white index card. After the letters were named they were removed and the child was presented a card containing only a vertical line. The child was asked to point to the side of the line where a circle would be placed in order to form each of the letters. Each of the four letters was presented to the child.

Additionally, the child was presented nonsense words printed in lower case on white index cards. The words contained easily confusable letters (e.g., g, r, u, p). Each word was presented for five seconds. When the word was removed the child was asked to select a target word from among the four alternatives (grup, grug, purg, prug). If the child failed to select the correct word the target word was presented again and he attempted to match it to the correct alternative.

On both of these tasks the dyslexic subjects made very few errors indicating minimal tendency to confuse the letters.

On a final task the subjects were given a printed word they could not read. In this task 12 relatively difficult words (fiercest, wintry, thrush) and eight nonsense words (e.g., labitoc, plosna) were printed individually on white index cards. The child was asked to read the word printed on the card. If he could not read the word correctly the card was removed and the examiner orally presented three multiple choice alternatives of the correct pronunciation of the word (e.g., labitoc, lavitoc, lapitoc). The child then selected the oral alternative he believed was correct. The dyslexics were correct on 58 percent of the words they could not read. These data indicate that these dyslexic boys did not have a perceptual deficit in the visual mode.

In addition, we found no evidence of perceptual deficit in the auditory mode. On each of 31 trials the examiner read aloud a target word to the child and, following a three second delay, read a pair of words, one of which was identical to the target word; the other was an acoustically similar foil. The child was asked to select the word which was identical to the target word. On 17 of the trials the discrimination was relatively difficult (e.g., elimiskopel: elikismopel/elimiskopel). The dyslexics were correct on 91 percent of the 31 trials.

These data indicate that the dyslexics did not have a visual or auditory perceptual problem of any serious magnitude.

Recall Memory

Over the 13 visits the children were given tests to assess recall of words, oral and written, as well as the recall of pictures.

The recall memory for pictures and words tasks consisted of six separate recall tests. Three different classes of information (oral words, written words, and pictures) were recalled under two retrieval conditions (order relevant and order irrelevant). The oral words were names of common objects spoken by the examiner at the rate of one per second. Written words were also names of common objects printed on white index cards (one word per card). Pictures were three and one-half by five inches color photographs of common objects. The children initially were presented a string of three items of information to recall. They were then presented a series of strings of information which increased progressively in length by one item (four, five, and six words) with one trial per string until they failed two consecutive trials.

The reading disabled boys were administered also five trials of strings of six digits for immediate recall.

In addition, the subjects heard strings of digits at the rate of one per second and then had to recognize these strings. After reading each string the examiner read a second string and the child had to decide whether or not the second string of digits was identical to the first. Four trials were presented at each of four levels of string length (three, four, five and six digits). At each level of string length two of the trials contained strings which were identical to each other and two contained pairs which differed, one differing in digits and one differing in the sequence of digits.

In order to test recognition memory for words in a story, a modified version of the familiar children's story *Stone Soup* was read to the children.

The story contained approximately a thousand words and required five and one-half minutes to read. The children were told that upon completion of the story they would be read a list of single words and asked to decide which words had appeared in the story and which had not. After reading the story the examiner read a list of 64 words to the child, and recorded the child's recognition response to each word. Half of the 64 words had appeared in the story and these 32 words included 20 words of high frequency and 12 of less frequent occurrence.

In order to assess recognition memory for words in a list the child was initially read a list of 32 unrelated words with instructions to attend carefully so that he could recognize them from a larger list. The words were similar in frequency and part of speech to the 32 words from the story. After reading the list the examiner read a second list of 64 words containing the original 32 words the child had just heard and the 32 new words matched to list words for frequency and part of speech.

The dyslexics did poorly on all the recall tasks, whether the order of report was relevant or irrelevant. Analyses of variance for each of the tasks revealed a significantly higher performance for the controls than for the reading disabled subjects.

However, it should be noted that five minutes of rehearsal training on recall of digits in which the subject was instructed to group and to rehearse the digits produced a significant improvement in recall of digits from less than one trial correct out of five to over three correct out of five.

Additionally, the dyslexics were poorer than the controls on recognition memory for both digits and words. However, the difference in recognition memory for words was only significant for the less familiar words, not for the familiar ones. Thus our data verified the results of others that dyslexics have a memory problem, but this problem seems to hold both for recall and recognition memory and for ordered as well as nonordered material (Vellutino 1979).

Decision Time

On 13 different occasions we administered to the children a different decision time task, 10 of which involved orally presented sentences or words, three involved pictures. In all these tasks the child had two keys in front of him, one for true items, one for false items. The child was to press one of the keys to indicate whether the item (oral sentence or picture) was true or false, and to do as quickly as possible. Thus the child might hear the sentence, "Salt is white" or "Plumbers print maps," or shown a picture of a purple rabbit or a cup on a saucer, and asked to decide on the validity of the item as quickly as possible.

There were three pairs of decision time tasks which were presented in both pictorial and oral form. One set of items was presented linguistically, through oral administration of sentences, while another set of items presented the problem pictorially. In the latter set of items the experimenter dropped a screen which simultaneously revealed a picture to the child and started a timer. The subject's response stopped the timer. One pair of tests involved the validity of the colors of objects, one pair involved the proper context of objects, and the final pair of tests required the subject to evaluate the relative sizes of two objects. We shall refer to these tests as color, context, and size sentences and pictures. Briefly, in the block of color items the child had to decide whether the color of an object was valid or not (the oral sentence might say, "Green is the color of spinach"; the picture might illustrate a red apple). For the context items the subject decided whether the context of an object was correct (e.g., a typical sentence might be, "Turtles live in lakes"; the pictorial item might display a picture of a radio in an oven). The size sentences were statements describing the relative sizes of two objects (a pencil is bigger than a boy). The size pictures depicted two objects drawn either in correct or incorrect proportion (a couch drawn smaller or larger than a hat). The subject had to decide whether this was a valid depiction of the object's true size in reality.

On all of these procedures the dyslexics, as a group, were significantly slower in deciding on the validity of the items. The mean response times to the sentence tasks averaged about 500 msec. for the controls and about 800 msec. for the dyslexics. The decision time data to the sentences were examined for the effect of syntactic structure, on the assumption that questions and passive sentences would require more time to evaluate than active and declarative ones. The data did not reveal an effect of passive voice nor a voice by group interaction. Similarly, there was no effect of declarative or interrogative sentence type. The syntax of the proposition appears to have had little effect on reaction times. The semantic content was relevant, for sentences with less familiar words had longer decision times.

The majority of the sentences to which the reading disabled boys showed very long decision times (greater than 800 msec.) had the critical information in the last word of the sentence. These included sentences like, "Fingernails are chewed by moths", and "Pumpkins and cabbages are fish". One-half of the sentences with decision times greater than 800 msec. had the critical information in the final word. This association did not occur among the controls.

We note that the simple motor reaction times of the subjects (i.e., the examiner simply said yes or no, and the subject had to hit the appropriate key) were fast (about 300 msec.) and similar in magnitude for controls and dyslexics. Thus the differences between the two groups in the decision time to evaluate sentences or pictures cannot be attributed to slower motor response times for the reading disabled boys.

It is also important to note that the speed of evaluating these sentences was not a function of the reflection-impulsivity dimension. Reaction time on the Matching Familiar Figures Test was independent of the decision time to the propositions for both reading disabled and control boys.

Long decision times in evaluating the sentences were associated with lower IQ scores among the controls but not among the reading disabled boys. Thus delays in evaluating the propositions among dyslexics was not a function of vocabulary level or the general intellectual construct assessed by standardized intelligence tests. All subjects had both short and long decision time trials. Also, there was remarkably good stability of decision time across the two years of testing. The average correlations were 0.5 for dyslexics and 0.4 for controls, but some of the correlations approached 0.8.

Examination of the scatter plots relating the various decision time tasks revealed that about seven of the 30 dyslexic children who were seen over the two-year period had consistently long decision times across all the sentence tasks. Figure 1 illustrates a typical scatter plot for the dyslexics for decision time to two sentence tasks administered about two years apart. Subjects 311, 109, 104, 317, 133, 110, and 127 comprised a special group of dyslexic boys who consistently required 200 to 400 msec. additional time to evaluate the validity of the symbolic information across many tasks.

Examination of the distribution of response times to the items on each test revealed that even for these seven boys, about one-third of their response times on many of the tests were similar in duration to those of the remaining reading disabled subjects and to many of the controls. The unusually long response times occurred only to about one-third of the items. Thus this group of seven reading disabled boys differed from the other children in the number of trials with very long decision times, not in the capacity to respond quickly to some items.

These data suggested that these seven boys might not be able to sustain the ability to evaluate oral information efficiently over the ten minutes required for each test. This idea was supported by an analysis of the changes in response time over the quartiles of each test.

Although the mean response times for the reading disabled boys were longer than those of the controls for every quartile of every task the

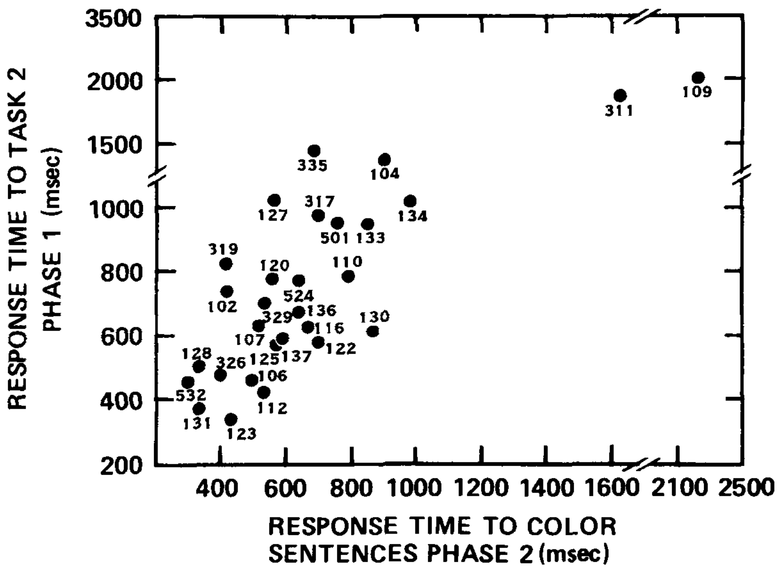

Figure 1. Scatter plot relating decision times on two of the sentence tasks for dyslexic subjects.

differences in response time between the fourth and the first quartile increased primarily for the dyslexics to the orally administered sentences. The difference in response time decreased over the quartiles of the test for color and context pictures.

Because we suspected that these results were due primarily to the performance of the special seven reading disabled boys we compared the data for these seven subjects with all the other reading disabled boys and all the control subjects. Over 90 percent of the control children had differences between quartile four and quartile one of less than 300 msec. for most of the sentence and picture tasks. Among the 22 reading disabled boys, less than one-third had differences between quartile four and quartile one of greater than 300 msec. But five of the special seven reading disabled boys had differences greater than 300 msec. for the five tasks involving the evaluation of orally presented sentences. But the quartile differences in decision time for the three picture tasks were far less striking for these seven special subjects. Because the picture items required as much mental effort as the sentences, the deterioration in efficiency to the sentences was not a general fatigue effect. If it were, the deterioration in response time over items should have appeared to the pictures.

Relationship to Blink Rate

Because spontaneous blinking while solving a problem is regarded as a measure of the arousal that accompanies mental work we coded blink rate on three of our tasks (Tecce, Savignano-Bowman, and Kahle 1978). The majority of subjects did not show a major change in blink rate over the course of each of the three tests. Although the correlations between blink rate and response time, separately for the first and second half of each test, were negative, the magnitudes of these correlations were not large enough to be statistically significant. Examination of the scatter plot for response time versus blink rate revealed that five of the seven special subjects showed a combination of very low blink rates (less than 0.2 blinks per sec.) and very long response times (greater than 700 msec.), suggesting a relation between a low blink rate and long response times, but only for the seven special reading disabled boys. On all three tests on which spontaneous blinks were coded the reading disabled boys who had the lowest blink rates belonged to the special group of seven who had been selected only on the basis of their long response times.

We note that the special seven were not different from the other 22 reading disabled subjects on many variables, including full scale IQ, recall of pictures, percent of familiar words recognized on the story and recognition of five digit strings. But five of the special seven with the lowest blink rates had very poor reading scores on both testing occasions. Only two other reading disabled boys had reading scores that low on the second administration. Additionally, three of these five showed little or no gain following rehearsal training for digits. One subject was unique in showing absolutely no gain following rehearsal training.

In sum, we conclude that there is a small group of dyslexic boys who may have a special deficit with respect to their sustained evaluation of symbolic information. They seem to be unable to sustain what is an automatic cognitive function for most children and adults; namely, the ability to extract and evaluate meaning from oral language for a period of eight to ten minutes. The extraordinarily low blink rate demonstrated by five of these special seven suggests that these subjects may not have been continually aroused during the task. It is not clear if this lower level of arousal reflects an unwillingness to sustain attention or, more profoundly, an inability to recruit and maintain a state of aroused attentiveness necessary for efficient performance on our tasks. If the long response times were due only to motivation we would not expect these boys to do well on some of the tests, but they did. Additionally, even these subjects had fast response times on some sentences. If the longer response times were due to generally low motivation we would have expected long response times to almost all the sentences and an equal degree of deterioration in speed for both sentence and picture tasks. That is why we favor the notion that these subjects are unable to maintain the ability to attend to and evaluate linguistic information despite motivation to do so. If this suggestion is affirmed by future research it would mark an advance in the search for the multiple etiologies of reading disability.

Summary

A group of 35 reading disabled boy and 35 matched controls were studied over a two-year period in order to evaluate the validity of traditional hypotheses about the causes of serious reading impairment in preadolescent boys for whom the common disadvantages of economic privation, bilingualism and emotional instability were absent. The popular hypothesis of perceptual deficit was not supported by the data, although the finding that most reading disabled boys have a short-term memory deficit was affirmed. The most important new findings was that about one-fourth of the reading disabled boys had serious difficulty in maintaining an efficient set to process and/or evaluate information, especially when that information was contained in oral speech.

References

Tecce, J.J., Savignano-Bowman, J. and Kahle, J.B. December 1978. Effects of visual distraction on contingent negative variation and type A and B CNV shapes. *In* D.A. Otto (ed.), *Multidisciplinary Perspectives in Event-Related Brain Potential Research.* EPA600/9–77–043, pp. 358–363.

Vellutino, F.R. 1979. *Dyslexia: Theory and Research.* Cambridge, Massachusetts: M.I.T. Press.