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ABSTRACT

Good and poor sixth grade readers served as subjects. Experiment 1 tested for immediate spatial orde memory of letters by giving children four or six consonants and havi. g them place the letters in the order in which they had appeared in a just-viewed stimulus. The consonants composing the strings were either positionally redundant (R) or nonredundant (NR) based on positional frequencies of letters in printed English. Poor readers were equal to good readers on four-letter strings, but inferior to good readers on both R and NR six-letter strings. Both reader groups were better in retrieving spatial order for R strings than for NR strings. Experiment 2 tested for immediate spatial order memory and immediate item memory for strings of eight digits and strings of eight consonants. Good readers were better than poor readers on all tasks. Performance on digits was better than performance with litters in both the order and the recall tasks for the two groups. The importance to the reading process of the poor reader short-term memory deficit for spatial order information is discussed in terms of recent evidence that positional redundancy is used to augment visual feature information in the identification of single letters. (Author)

Immediate Spatial Order Memory and Item Memory in

Sixth Grade Children as a Function of Reader Ability

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Running Head: Order Memory and Reading Ability

Footnote:

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Immediate Spatial Order Memory and Item Memory
in Sixth Grade Readers as a Function of Reader Ability

Thompson and Massaro (1973) provide evidence: a) that the individual letter is the basic perceptual unit involved in reading, and b) that redundancy (i.e., letter predictability based on knowledge of spelling patterns) is operative at the stage of the synthesis of visual features of individual letters. Thus, redundancy appears to augment direct visual information at the level of identification of individual letters.

The finding of Katz and Wicklund (1972) that good and poor readers do not differ in search time for an individual letter embedded in a random (nonredundant) string of letters suggests that no reader ability differences occur in the utilization of direct perceptual information about visual features present on a printed page. However, Mason (1975) raised the possibility that good and poor readers might be different in their abilities to augment visual feature information with redundancy information. Redundancy was manipulated as letter position redundancy; positional redundancy is based on a correlation between two physical dimensions: position of a letter within a multiletter configuration and the visual features used to identify a letter. For example, in printed English the letter "c" frequently occurs in the first position of a six-letter string and less frequently elsewhere. The results of four experiments using the visual search paradigm indicated that poor readers were equivalent to good readers in identifying individual letters only when low redundant (i.e., non-English-like) displays were used. With low redundant displays, visual information about distinctive features is the only source of information available for letter identification. However, good readers were faster than poor readers on both word displays and redundant nonword displays.

Mason's data (1975) raised the possibility that poor readers suffer from a spatial order perception deficit which would reduce positional redundancy as a source of information that can be utilized to augment visual feature information, since positional redundancy is dependent on the preservation of spatial order information. However, since the redundancy used in the Mason (1975) studies is based on frequencies of occurrence of letters in varying spatial (serial) positions in printed English (Mayzner & Tresselt, 1965), one could argue that poor readers do not read much and hence are unaware of positional frequencies of letters in printed English. In effect, the issue is whether poor readers do not read proficiently partly because of a spatial order perception deficit that precludes their use of positional redundancy in single letter identification or whether poor readers do not utilize positional redundancy because they have not read in sufficient quantity to have learned well the positional frequencies of letters in printed English.

The purpose of the two experiments to be reported in this paper was to test specifically for spatial order memory differences as a function of reader ability. There is evidence (Crossman, 1960; Bjork & Healy, 1970; Estes, 1972) that order information and item information have separate representations in memory. Whereas order memory and item memory have been studied primarily by the analysis of transposition errors (an item is correctly remembered, but is placed in the wrong spatial or temporal order; there are, for our purposes, several objections to investigating order memory by scoring recall protocols for correct order. Most importantly, order memory is made dependent on recall with that technique, and if good and poor readers differ in item memory, they will show a difference in order memory which could be spurious. To circumvent this difficulty Experiments 1 and 2 use a different paradigm to directly test for spatial order memory. The child is shown a horizontal string of lower case consonant letters which is removed as soon as the letters have been read aloud at a fixed rate. The subject is then immediately given a set of small tiles (similar to those used in word games) which have been shaken up in a container, with each letter that had appeared in the stimulus represented on a separate tile. Instructions to the child are to arrange the tiles in the order in which they had originally occurred in the stimulus. Thus, subjects are given all the items they had just viewed and are asked to retrieve only order information for the items.

Experiment 1 uses lower case consonant letters in two different string lengths (four and six) with two levels of positional redundancy (high or low) within each string length. Of interest in Experiment 1 are the following: a) are poor readers inferior to good readers in retrieving spatial order information?, b) does positional redundancy facilitate memory for order information?, c) do poor and good readers show differential effects of positional redundancy on retrieval of spatial order information? If poor readers have not read enough to be sensitive to positional frequencies of letters in printed English, we would expect no differences in their performance as a function of positional redundancy.

Experiment 1

Method

Subjects. Thirty-two sixth grade pupils from the Tolland Middle School served as subjects. Good and poor reader groups (16 children in each group) were formed on the basis of the previous year's Science Research Associates (SRA) reading comprehension scores made available by the school. In addition, the Word Recognition portion of the Wide Range Achievement Test (WRAT) was administered to each subject by the experimenter. The median of WRAT scores, with grade equivalents in parentheses, was 54.5 (9.2) for the good readers and 31.5 (4.9) for the poor readers.

Stimuli. Horizontal strings of lower case consonants (Trans-Artype No. T 1141, Franklin Gothic, 36 pt.) were used as stimuli. String length consisted of either four or six consonants. For each level of positional redundancy (Redundant or Nonredundant) within each string length, the same consonant letters were used, but in different spatial arrangements based on the Mayzner and Tresselt (1965) single letter frequency counts for letters in all positions for either four or six-letter words in printed English. Summed positional redundancy is the sum of the frequencies of the letters in a given string. For example, the stimulus string "phmvld" has a summed positional frequency of 1191; the same letters arranged as "vmdlhp" have a summed positional frequency of 241. "Phmvld" was designed a six-letter Redundant (R) string while "vmdlhp" was a six-letter Nonredundant (NR) string.

Each stimulus string was centered on a 4" x 6" (10.16 x 14.24 cm) card. All letters appearing within any one stimulus string were centered individually on both sides of a 1.25 cm white plasterboard square and sprayed with a clear glossy protective covering. The letters for each stimulus string were placed in separate containers.

There were four R stimuli (two four-letter strings and two six-letter strings) and four NR stimuli (two four-letter strings and two six-letter strings).

The same consonants occurred in the R and NR sets, but in different locations within the strings.

Design. There were two between-subject factors: reader ability (good or poor) and positional redundancy of the strings (R or NR). String length (four or six consonants) was a within-subject factor. Each subject had four trials (two on each string length). Order of presentation of string length and stimuli was counterbalanced in a Latin Square. Eight subjects in each level of reader ability were randomly assigned to either the R or NR condition, with two subjects in each level of reader ability and positional redundancy receiving one of four orders.

Procedure. The stimulus was displayed on a Gerbrands card changer (Model G 1150). The subject read each letter aloud, from left to right, at a rate of two letters per second. (The experimenter tapped out the rate the subject was to follow.) The stimulus was removed after two seconds for a four-letter string and after three seconds for a six-letter string by the experimenter pressing a button which replaced the stimulus card in the card changer with a blank white card. The subject was then presented with the letters just viewed by having the experimenter spill out the contents of a small container which contained all the appropriate letters on 1.25 cm square tiles. The subject was instructed to take the individual letters and arrange them as best he could in the order in which they had appeared on the stimulus card. Each subject's response was recorded and scored for absolute number correct in each spatial location.

Results and Discussion

Performance was virtually perfect with four-letter strings for both R and

NR conditions. Only one subject (a poor reader on a NR string) made an error on a four-letter string.

Performance on the two types of six-letter strings is shown in Table 1.

Insert Table 1 about here

An analysis of variance was performed on the number of letters placed in correct positions for six-letter strings, with reader ability (good or poor) and redundancy (R or NR) as between-subject factors.

The main effect of reader ability was significant, $\underline{F}$ (1,28) = 30.28, $\underline{p} < .001$; good readers were better than poor readers at reconstructing the spatial order of six-letter consonant strings. This strongly suggests a capacity difference for spatial order memory for good and poor readers, since both groups showed essentially perfect performance on four-letter strings but differed significantly when the length of the strings was increased to six letters. Both good and poor readers were well above the chance level for mean correct items (.96).

The main effect of positional redundancy was also significant, $\underline{F}$ (1,28) = 30.28, $\underline{p} < .001$; performance was better on the R stimuli than on the NR stimuli. It is clear that positional redundancy improves the memory code for order information; the spatial order of "phmvld" is easier to retrieve than is the spatial order of "vmdlhp."

The Ability x Spatial Redundancy interaction was not significant, $\underline{F}$ (1,28) = 3.07, ns. The Mason (1975) experiments indicated that poor readers did not utilize positional redundancy in the identification (or synthesis) of individual letters. In Experiment 1, the letters were given to the subject and there was no need for synthesis. That poor readers in Experiment 1 benefited as much as did good readers from stimulus positional redundancy in retrieving order information would argue against an unfamiliarity with positional frequencies of letters in printed English as being responsible for their inability to augment visual feature information with positional redundancy information in the visual search paradigm used in the Mason (1975) experiments.

The hypothesis of a spatial order perception deficit in poor readers is supported by the results of Experiment 1. It would appear that poor readers either do not encode or cannot retrieve spatial order information as well as do good readers.

Experiment 2

According to the Anderson and Bower (1972) model of free recall processes, context is used to retrieve item information. Spatial location (where a letter is positioned within a multi-letter string) is a form of context. Furthermore, Bruder and Segal (1972) have shown that adults can use spatial location in organizing their recall. It would seem, then, that if poor readers are deficient in spatial order perception they would also be deficient in recall, since they cannot use spatial context for retrieval purposes. However, several investigators (Bakker, 1972; Senf, 1969) have provided data that suggest that good and poor readers do not differ in their ability to recall stimulus items, but only in their ability to reproduce the sequences of stimulus items. That these investigators found sequencing differences (order memory differences) but no recall differences (item memory differences) as a function of reader ability may be due to the facts that sub-span memory sets (two to four items) were used and that the rate of loss of order information is more rapid than that of item information (Bjork & Healy, 1970; Estes, 1972).

Experiment 2 extended the size of the memory set further. Both immediate order memory and immediate item memory for eight items were investigated as a function of reader ability and type of material. The two types of materials used were consonants and digits.

Method

Subjects. The 240 sixth grade pupils in the Tolland Middle School are organized by the school into three homogeneous "teams." The 80 children from three sixth grade classrooms forming one of these teams served as subjects for Experiment 2. Each child was placed in one of two reader ability groups (good and poor) on the basis of a median split of the SRA reading comprehension scores taken the previous year and made available by the school. In addition, the WRAT was administered to each subject by the experimenter. The six subjects for whom SRA scores were not available were assigned to the two reader ability groups on the basis of their WRAT scores. The median WRAT scores, with grade equivalents in parenthesis was 49 (8.1) for the good readers and 33 (5.2) for the poor readers.

Stimuli. Stimuli consisted of random (low redundancy) strings of either lower case consonants and random strings of eight digits (Trans-Artype No. T 1141, Franklin Gothic, 36 pts.). The symbol 0 was not used as either a digit or a letter. Each stimulus string was centered on a 4" x 6" (10.16 x 14.24 cm) card. The individual letters or digits appearing on each stimulus card were centered on 1.25 cm square tiles, as in Experiment 1, and placed in separate containers.

Design. A repeated measurements design was used, with each subject receiving four trials (one on each task). The four tasks were to: place eight letters in correct order; place eight digits in correct order; recall as many of eight letters as possible, and recall as many of eight digits as possible. Stimuli and tasks were counterbalanced in a Latin Square, with ten subjects in each level of reader ability receiving one of four orders. Letter and digit tasks were always presented alternately in order to minimize interference among tests.

Procedure. The apparatus and procedure used in Experiment 1 were used for the two spatial order memory tasks in Experiment 2.

For the two free recall tasks, the procedure was identical to that used for the spatial order memory tasks, except that following offset of the stimulus, the subject was given paper and pencil and instructed to write down as many letters (or digits) as he could remember having seen. The subject was told that the order in which he wrote them down was not important.

The stimulus remained on for four sec. for all four tasks, during which time subject read the items aloud from left to right at a rate of two items per sec.

Results and Discussion

Order Memory. The number of consonants placed in correct spatial positions and the number of digits placed in correct spatial positions was scored for each subject and entered into an analysis of variance with reader ability (good or poor) and order of task presentation (four orders) as the between-subject factors. The within-subject factor was type of material (letters and digits). Results are shown in Table 2 under Order Memory. The chance level of performance was

Insert Table 2 about here

1.01. The main effect of reader ability was significant, $F(1,72) = 8.12$, $p < .006$; good readers were better at reconstructing the spatial order present in both letter and digit displays than were the poor readers. The main effect of type of material was also significant, $F(1,72) = 18.66$, $p < .001$; more digits than letters were placed in correct positions. The main effect of order of presentation of tasks was not significant. None of the two-way interactions involving reader ability, presentation order, and type of material were significant.

The data on spatial order memory from Experiments 1 and 2 point to a poor reader deficit in the ability to reconstruct the spatial arrangement of discrete items. Informal observation suggested that if confidence ratings had been used, the good-poor reader differences would have been even more exaggerated. Good readers, after arranging the tiles, were apt to make appropriate remarks such as "I'm sure that's not right," or "it looks wrong." In contrast, poor readers generally appeared less critical of their arrangement of the tiles. Since poor readers showed the same incremental effects due to positional redundancy (Experiment 1) and type of material (Experiment 2) as did the good readers, memorial processes may be similar for the two groups. The difference would seem to be in the ability to encode and/or retrieve spatial order information per se.

The number correct for good and poor readers shown in Tables 1 and 2 do not provide a reasonable estimate of short-term memory capacity for order information. With a forced-choice paradigm, the total number correct includes the number correct by chance. In addition, the time parameters are important, since order information (Bjork & Healy, 1970; Estes, 1972) decays rapidly. An increase in the number of items entails an increase in time during which order information decays. While we cannot ascertain short-term memory capacity for order information from the paradigm used in Experiment 1 and 2, it appears from these data that the capacity will vary with type of material and that it is less for poor readers than it is for good readers.

Item Memory. The number of letters correctly recalled and the number of digits correctly recalled was scored for each subject and entered into an analysis of variance identical to that used for order memory. Results are shown in Table 2 under Item Memory. The main effect of reader ability was significant, F (1,72) = 11.67, p < .002; good readers were better at the recall tasks than were the poor readers. The main effect of type of material was also significant, F (1,72) = 95.20, p < .001 that digits were recalled better than letters. On the recall task, in contrast to the order task, this is not surprising since the total set of digits is much smaller than the total set of consonants. In recall of 8 digits, there is only a small possibility of making an error by guessing. The main effect of task presentation order was not significant. The Reader Ability x Type of Material interaction reached marginal significance, F (1,72) = 4.75, p < .05. On digit recall, poor readers were closer to good reader performance than they were on letter recall. This probably reflects the higher probability of being correct by chance on [illegible] git recall task. If recall was scored by subtracting the number of erro[illegible] from the total number correct, overall recall scores would be even more exaggerated in favor of the good readers.

Intrusive Errors. On the free recall tasks, if subject recalled either a digit or a letter that was not present in the stimulus, it was scored as an intrusive error. On the digit recall task, good readers made only 1 intrusive error and poor readers made a total of 9 intrusive errors. (The few intrusive errors made on the digit recall task is undoubtedly attributable to the fact that there were only two ways to make an intrusive error with 8 digits as the stimulus.) The difference between good and poor reader intrusive errors on the digit recall task was significant, χ^2 (1) = 6.40, $p < .02$. On the letter recall task, the good readers' total number of 24 intrusive errors was significantly less than the poor readers' total number of 44 intrusive errors, χ^2 (1) = 5.88, $p < .02$. Inspection of the intrusive error data suggested that poor readers tended to incorrectly recall vowels despite the fact that only consonant letters were used as stimuli. Since the letter "q" was present in one string, the vowel intrusion "u" during recall would appear to be not unreasonable. Good readers incorrectly recalled 12 vowels, 8 of these being the response "u." In contrast, poor readers incorrectly recalled 25 vowels, 12 of which were the response "u." Taking the total number of vowel intrusions made, good readers incorrectly recalled fewer vowels than did the poor readers, χ^2 (1) = 4.57, $p < .05$. With the "reasonable" intrusion "u" eliminated from the data, good readers made fewer "unreasonable" vowel intrusion errors than did poor readers, χ^2 (1) = 6.37, $p < .02$.

The greater number of intrusive errors made by poor readers on both digits and letters suggests a less constrained search set, which, in turn, suggests possible retrieval differences between good and poor readers. The extent to which a short-term spatial order memory deficit affects retrieval processes by enlarging the search set is a matter for future investigation.

SRA and WRAT Correlation. A Pearson Product Moment Correlation was run between each subject's WRAT score and SRA score. The r of .841 (N = 74) was significant, $p < .001$. Since the WRAT tests word recognition and the SRA tests reading comprehension, the high correlation between the two tests is consistent with the contention (Katz & Wicklund, 1971; 1972; Shankweiler & Liberman, 1972) that the major differentiation between good and poor readers is at the level of individual word rather than at the level of connected text. Data from the present studies, which show a poor reader deficit in spatial order memory, in conjunction with data (Mason, 1975) that poor readers do not utilize spatial redundancy information in the identification of single letters, also suggest differences at the word level. Words, after all, consist of letters that occur, by and large, in positionally redundant locations.

Conclusions

The notion of a sequencing or order deficit in poor readers is by no means new. Bakker (1972) summarizes a sizeable body of evidence that links disturbed reading to a disturbance in temporal order perception. Bakker does not, however, present a precise hypothesis of just how temporal order perception is related to the actual reading process. Furthermore, it is not clear from the studies cited by Bakker (1972) whether the difficulty is with temporal ordering, with spatial ordering, or with both temporal and spatial ordering. As Bower (1971) points out, temporal position and spatial location can map onto the same abstract conceptual elements for "position-in-series," and spatial and temporal locations are particularly susceptible to interaction with one another. It will take more sophisticated paradigms than the ones used to date to untangle true temporal order effects from spatial order effects.

The two order memory experiments reported in this paper point to an order memory deficit in poor readers. Using a paradigm in which all the correct items are given to subjects and the task set the subject is solely to retrieve the spatial order of the items, poor readers were equivalent to good readers only on four item length strings. With 6 consonants, 8 consonants, and 8 digits, poor readers were significantly less able than good readers to retrieve spatial order information for the items making up the strings.

There is evidence (Makita, 1968; Rozin, Poritsky & Sotsby, 1971) that an alphabetic writing system makes demands upon the reader not present in a semantic or idiographic writing system. One of these demands is that the order of letters must be preserved at the level of the words, for the meaning of a word depends upon the order of the letters rather than upon the letters themselves (i.e., "much" or "chum;" "from" or "form," etc.). There are data (Leene & Bakker, 1969) that poor readers (or poor temporal order perceivers) make as many as four times more "order" errors in reading and dictation than do good readers (or good temporal order perceivers). However, Shankweiler and Liberman (1972) have found that sequence reversals account for only a small proportion of total errors made by poor readers.

We would suggest, therefore, that a more fundamental demand on an alphabetic writing system for proficient reading is the ability to augment visual feature information with positional redundancy information at the level of identification of individual letters. Knowledge of positional redundancy may be based on more abstract structures such as knowledge of English morphological rules. The studies by Mason (1975) showing that good and poor readers are differentiated by the utilization of spatial redundancy in identifying individual letters, in conjunction with the studies reported in this paper showing that poor readers are less able than good readers to encode, preserve and/or retrieve the spatial relationships existing in a string of discrete letters, would support the hypothesis that a spatial order perception (or memory) deficit diminishes positional redundancy as a source of information for poor readers. With an alphabetic writing system, the redundancy of spoken language (temporal in nature) is carried over in the written language, where it becomes spatial in nature. It may well be that an alphabetic writing system makes demands upon short term memory that are too great to be met by a process of letter identification based solely on the analysis of visual features. Proficient reading may be strongly dependent upon the more rapid identification of letters made possible by augmenting visual feature information with positional redundancy information.

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Table 1

Mean Number of Letters Placed in Correct Positions as a Function of Spatial Redundancy and Reading Ability - Exp. 1

	Type of Six-Letter Consonant String	
Group	Spatially Redundant	Spatially Nonredundant
Good Readers	5.56	4.75
Poor Readers	4.75	3.06

Table 2

Mean Number of Correct Responses for Order Memory and for Item Memory as a Function of Type of Material and Reading Ability - Exp. 2

	Type of Eight Item Task			
	Order Memory		Item Memory	
Group	Consonants	Digits	Consonants	Digits
Good Readers	3.35	4.35	5.70	6.70
Poor Readers	2.45	3.73	4.80	6.38