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ABSTRACT

In two experiments, visual and auditory memory were tested for good and for poor readers from the upper elementary grades. Under experimenter-blind conditions, no reading group differences existed for single-mode presentation in recognition frequency or recognition latency. With a multimodal presentation, latencies for poor readers were similar to those for the single-mode presentation. Good readers, however, had significantly faster latencies with multiple input. Generally, results supported dual encoding and self-terminating memory search hypotheses for previously encoded stimuli. Implications of the latency differences between reader groups are discussed with respect to the reading process and reading theory. (Author)

Memory by ear and by eye: Relationships to reading achievement

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As Conrad (1972) has pointed out, there is an obvious need to hold onto words and/or ideas while encountering subsequent information in order to read with comprehension. Conrad has argued that a phonological based code in short-term memory appears to be the most functional for the majority of normal readers although other nonspeech codes may be activated as necessary. Other theorists such as Samuels (Samuels & Anderson, 1973) have stressed the role of visual memory in reading.

Assuming the necessary role of memory processes in reading, one logical extension of this notion is to implicate deficits in memory functioning as at least a partial cause of reading disability (e.g., Kirk & Kirk, 1971). However, the evidence for this latter concept is conflicting as researchers have attempted to compare good and poor readers on a variety of memory and memory based tasks. Among those finding differences are Samuels and Anderson (1973), whose data revealed varying performance in visual recognition memory and visual paired-associate learning tasks, while Kolers (1975) has found differences in pattern recognition. Many others, however, have failed to substantiate visual memory differences (Clifton-Everest, 1974; Golden & Steiner, 1969; Vellutino, Steger, Desetto & Phillips, 1975) between good and poor readers.

Farnham-Diggory and Gregg (1975), however, found that auditory memory scan speed under a Sternberg-type paradigm deteriorated relative to visual scan in poor readers over trials. Similarly, in aural serial learning Katz and Deutsch (1964) found superiority of good over poor readers, while Golden and Steiner (1969) reported superiority in three auditory functions for good readers over poor.

The fact that no consistent findings have yet emerged from the experimentation in the area may stem, at least in part, from the variety of methodological problems which present themselves in this body of research. In several earlier studies, there has existed the potential for confounding general intellective differences with reading ability. While Samuels and Anderson (1973) did attempt to control statistically for general ability, other studies finding memory differences have failed to control for intelligence at all (e.g., Farnham-Diggory & Gregg, 1975; Katz & Deutsch, 1964; Kolers, 1975). Still others have done so inadequately by selecting participants from a wide span of "average" intelligence (Rudoff & Quinlan, 1964; Vellutino et al., 1975), thus leaving the possibility for intellective differences to exist. The other studies employed matching procedures which had as their purpose the ruling out of general ability as a factor, while at the same time allowing for the widest possible reading group divergence.

Certain other features of these earlier investigations make it difficult to draw conclusions concerning reading group differences in memory or the lack thereof. One problem shared by all such studies has been the apparent failure to control for potential experimenter bias in their designs. Given experimenter knowledge of reading group membership coupled with certain expectations, well-known bias effects (Rosenthal, 1966) and/or differential demand characteristics on participants (Orne, 1962) may operate. Whether such effects have indeed been present in these studies is, of course, unknown, as is the directionality of any potential biases. The present investigations were designed to rule out these unknown factors by the arrangement of research conditions which were blind with respect to reader classification.

LaBerge and Samuels (1974) have theorized that for the subskills of reading there are two criteria for achievement: accuracy and automaticity. Achievement proceeds in the direction from accuracy to automaticity and accuracy is not a sufficient criterion for readiness to build on particular subskills. If subskills are not automatic, attentional processes may be diverted to the lower level subskills at the cost to other, higher order skills. Thus it is that good and poor readers may be indistinguishable on accuracy measures, both recognition and recall frequencies. On the dimension related to the automaticity of the recognition/decision-making process, however, good and poor readers may differ considerably.

In order to more closely investigate the components of accuracy and automaticity in the memory processes of good and poor readers, Experiment 1 was designed using a recognition/reaction time format. This paradigm allows the distinction to be made between frequency of correct responses and latency of response. The latter variable of response speed has been considered by other theorists in addition to LaBerge and Samuels (e.g., Doehring, 1976; Vellutino et al., 1975) as the key to skilled reading as memory buffers are activated repeatedly. Whereas measures of memory power such as frequency of correct recall or recognition may be insensitive to reading group differences, recognition latencies may provide information on a potentially important set of reader characteristics critical to skilled reading. A recognition/reaction time paradigm also opens the possibility of comparison of search times for stimuli that are presented during a learning phase with search times for stimuli not presented, both processes likely required in reading. Poor readers may use different strategies than good readers in either or both categories. No information presently exists on this question. Third, verbal responses are not required. This feature removes the potential confounding of verbal response requirements with input mode--responses are output under equivalent conditions.

Experiment 1 compared poor and good readers on both recognition accuracy and reaction times, for stimuli previously encountered and those not previously encountered. Comparisons were made across auditory, visually presented word and visual pictorial modalities of presentation (e.g., Williams, Williams & Blumberg, 1973). This comparison has not been directly extended to reader group/memory investigations. Such a comparison is theoretically valuable in pinpointing the nature of those particular processes which may differ in reader groups. Hypothesized were longer reaction times for poor readers, particularly for auditory input (Farnham-Diggory & Gregg, 1975), and pictorial superiority in both frequency and latency data, as each reflects dual encoding (Paivio, 1971).

Experiment 1

Participants

Participants in Experiment 1 were 18 pairs of students in the 4th, 5th and 6th grades drawn from a public school in Lincoln, Nebraska. Students involved in the study were selected initially on the basis of average or above average general mental ability as defined as a stanine score of 4 or better on the Otis-Lennon Mental Ability Test. From this large pool of children, the principal then selected children whose most recent score on reading subtests of one of three standardized achievement tests used by the school system was at least two stanines (one standard deviation) below their Otis-Lennon level. For fourth graders, the Reading subtest of the Metropolitan Achievement Test was employed. For fifth graders the subtests were Reading Comprehension and Vocabulary on the Iowa Test of Basic Skills; and for sixth graders, the Reading Comprehension and Vocabulary subtests of the Stanford Achievement Test. For each of these individuals, a counterpart was then selected who had the same Otis-Lennon stanine, grade and sex, but scored at or above his or her grade level in reading ability. This procedure resulted in an overall group of participants with a mean stanine score of 65 on the Otis-Lennon Mental Ability Test. Reading subtest mean stanines were 3.3 for the poor reader group and 7.9 for the good reader group. Since the Otis-Lennon requires reading of items, it may be assumed that the IQ scores of the poor readers were somewhat underestimated.

Materials

Materials for Experiment 1 were a pool of 75 common monosyllabic nouns (e.g., bird, star) chosen from beginning vocabulary words of the System I reading program of the Omaha Public Schools. Each word had a counterpart line drawing with a recognizability of above 90 percent for first grade pupils. Visual stimuli were reverse field slides (yellow on black) containing either the line drawing or block print word. Auditory stimuli were tape recorded by a male adult.

Procedure

Presentation of all materials, auditory and visual, was controlled by a Wollensak 2551 tape recorder attached to a Wollensak Digi-Cue Multimedia Programmer (Pro 6 Model). The materials to be recalled were presented to the participants in a mixed sequence of visual and auditory modes. Earlier research (Farnham-Diggory & Gregg, 1975) has shown that poor readers may be particularly susceptible to modality switching. Three alternative formats were employed: auditory, via tape recorder and headphones; visual, by a block print slide of the word; and pictorial, by a line drawing slide. Interstimulus intervals were controlled by silent tones on the tape which were processed through the programmer to a Kodak 750 carousel projector, while presentation duration was controlled by a Lafayette 43011 tachistoscopic lens.

For the recognition/reaction time phase, a Lafayette 54019 stop clock was started simultaneously with the opening of the tachistoscopic lens or the onset of the auditory stimulus. Participants were instructed to indicate whether they had previously seen or heard the stimulus in the presentation phase by pressing the appropriate button on a lighted Yes/No response panel. Participant response on the panel terminated the run of the clock. Participants were seated at a table approximately two meters from a screen upon which the visual materials were projected. Projected stimuli subtended a visual angle of approximately 5°.

As a part of the warmup activity, mean "naming" latencies were obtained for a 3 Yes and 3 No slides using a modification of Kirsner's (1972) method. Three stimuli, one auditory, one visual word, and one pictorial were then presented. Six additional stimuli were then shown, consisting of the three just presented (Yes) and three stimuli the participants had not seen or heard before (No). Participants indicated their responses by pressing the appropriate button.

Following the warmup trials, and a brief interval in which the experimenter changed the tape and slide tray and answered any questions, 15 target stimuli were presented at a 1.0 second presentation/2.0 second interstimulus rate. Five target stimuli were presented in each modality and randomly ordered in groups of three to counterbalance for serial position effects. After a 30 second buffer period, the presentation was followed by 30 probes containing five new stimuli in each modality plus the previously presented 15 which appeared in their original (presentation) modality. Stimuli, both old and new, were completely randomized for position. Participants were instructed to press the Yes button if they had seen or heard the item in the presentation and the No button if they had not. The first dependent measure was the frequency of hits and correct rejections. The major dependent measure, reaction latency, was defined as the interval between onset of the stimulus and the button press.

All research conditions in this and the subsequent study were blind with respect to reading ability. Selection of participants, soliciting of parental permission, and scheduling were directed by school personnel. Participants were advised that their involvement was completely voluntary and that they could choose not to participate or could withdraw at any time. Participants were debriefed at the end of their experimental sessions and requested not to discuss the nature of their experience with their classmates.

Analysis

Data were analyzed within a 2 X 3 X 2 ANOVA design with repeated measures on the latter two factors. The factors included the two levels of reading group, the three modalities and the Yes/No response dimension. Frequency of correct responses was the number of correct identification of new stimuli as No (correct rejections) and previously presented stimuli as Yes (hits). Since a miss could have been caused by failure to input and encode rather than search and output, mean reaction times for each subject for the within-subjects dimension were computed for correct responses only.

Results

Since raw reaction time correlated very highly with the times corrected for naming latency ($r = .86$) and results of data analysis were virtually identical, only raw reaction time scores and hit frequency data are reported. Mean hit frequencies and latencies are presented in Table 1.

Insert Table 1 about here

Frequency data: Analysis of the number of hits and correct rejections showed that new (No) items were identified correctly significantly more often than old (Yes) stimuli, $F\ (1,30) = 16.38$, $MS_e = .927$, and also indicated a significant effect of mode, $F\ (2,60) = 6.43$, $MS_e = .467$, which reflected a higher correct identification of pictorial stimuli. Inspection of Table 1 reveals that there was relatively little difference in identification frequency of old and new pictorial stimuli, while identification of new auditory stimuli was much more accurate than the identification of old. This interaction between modality and response dimension was significant, $F\ (2,60) = 4.74$, $MS_e = .518$; however, it should be noted that No responses were consistently more often correct within each modality and that pictures were the most accurately identified stimuli within both the Yes and No dimensions.

Reaction time data: For the reaction time measures the Yes/No dimension was significant, $F\ (1,30) = 8.55$, $MS_e = .315$, indicating the relatively greater amount of time to make a No decision. Thus, participants overall decided somewhat more slowly but more accurately about new stimuli than about old. While modality had a significant effect upon frequency of correct choices, latency differences across modality only approached significance ($.05 < p < .10$)

Discussion

No reading group differences were present as either main or interactive effects in either the frequency or latency data. The latter lack of differences was somewhat surprising in light of some earlier findings of contrasts in reaction time (e.g., Farnham-Diggory & Gregg, 1975) between poor and good readers. The non-differences under the present conditions, however, many reflect the somewhat more stringent test imposed by controls for intellective variables exercised in the present study, together with the blind conditions of the present experiment.[1]

The finding of slower No times versus Yes times suggests that a self-terminating search (Theios, Smith, Haviland, Traupman & Moy, 1973) may be operating such that subjects exit their search when a match is made in Yes decisions but must exhaustively search the list under the No condition.

The trend toward faster times for picture recognition under the Yes condition supports the hypothesis of parallel search of visual memory proposed by Paivio (1971) and Bower (1970). Together with the significantly higher number of correct recognitions this finding is supportive of a hypothesis of dual encoding (Paivio, 1971) in elementary school children. It is noteworthy, however, that No latencies average as long for pictures as for visual words and auditory words, suggesting that exhaustive serial search (Sternberg, 1966) may be required irrespective of modality under this condition.

Experiment 2

In Experiment 1, participants had encountered a unimodal presentation of a stimulus in which they attended successively to auditorily presented words, printed words, or pictures. An alternative procedure and one which is more closely parallel to much of reading instruction, is to allow simultaneous input in the auditory and visual modalities. Poor readers, it has been argued (Kahn & Birch, 1968), have particular difficulty transforming information across channels, while for good readers the process is a more facile one. Thus, multimodal presentations may not necessarily assist the poor reader in a memory task which contains any elements of speededness. The normal reader, however, may be more likely to integrate inputs from multiple channels quickly and effectively. Thus, improved memory search times may be predicted for good readers in contrast to the poor where less or no improvement may occur.

The dual-encoding hypothesis would predict that recognition should be generally improved and latency of response reduced for visual words and for auditory word stimuli with multimodal as opposed to unimodal input. Since presumably pictures are already encoded within both visual symbolic and verbal coding systems by virtue of being spontaneously labeled, while visual or auditory words are not as effectively dual encoded, the addition of "external" coding in the pictorial dimension should facilitate responding in these latter categories with both systems available for search.

Subjects

Twelve pairs of fourth, fifth, and sixth grade students were selected from a second Lincoln, Nebraska public school in the manner described in Experiment 1. The mean for general ability for the subjects as measured by the Otis-Lennon was 6.5, and the mean stanines for reading ability were 4.0 for the poor reader group and 7.4 for the good readers.

Materials

Materials were drawn from the noun pool used in Experiment 1. Slides for the presentation phase were diagonally split with the visual words and pictures presented on the same slide with location randomly varied. The recognition stimuli were the same as Experiment 1.

Procedures

The apparatus for Experiment 2 was identical to that of the Experiment 1 with the following exceptions: A Lafayette 41010 (KT-800) automatic projection tachistoscope was used for slide presentation and a Lafayette 54419-A Digital Clock/Counter was used to measure reaction times. Procedurely, the major change was the presentation of the 15 target items in all three modalities simultaneously, that is, the split slide was presented as the word was pronounced on tape. Naming latencies were not taken during this study due to the close correspondence found previously between raw and corrected scores in Experiment 1.

Results

The mean latencies and frequencies for Experiment 2 are given in Table 2.

Insert Table 2 about here

Frequency data: Table 2 reveals no significant differences in frequencies as a result of the main effects of group, modality, or the Yes/No dimension. A significant interaction between group and modality, $F(2,44) = 3.22$, $MS_e = .274$, was detected but was qualified by a significant triple interaction between group, modality and the Yes/No dimension, $F(2,44) = 3.60$, $MS_e = .442$. The frequencies of correct responses for visual words did not differ significantly as a result of group or the Yes/No dimension, but within the auditory condition the good readers correctly identified No responses more often than any other group X response condition. Within the picture condition poor readers correctly identified No responses more often than any other group X response condition.

Reaction time data: Inspection of the reaction times reveals significant main effects of reading group, F (1,22) = 5.65, MS_e = .687; modality, F (2,44) = 9.35, MS_e = .079; and the Yes/No response dimension, F (1,22) = 8.93, MS_e = .123. No interaction effects were significant.

Discussion

It can be seen in Table 2 that the good readers reacted more rapidly than the poor readers and that, in general, auditory recognition was slower for both groups than visual word and picture recognition. As in Experiment 1, Yes responses were consistently more rapid than No responses, supporting the hypothesis of a self-terminating search for old stimuli in memory and an exhaustive search for new, for both good and poor readers. When faced with the task of deciding whether or not an encountered stimulus is a member of a previously encountered set of stimuli, subjects appear to search their memories until a match is encountered, if one exists. At that point, the search is terminated and the response made. However, if no match is found, the entire memory set must be searched exhaustively before a decision can be made.

Comparing the pattern of means for reaction times in Table 2 with those in Table 1, it can be seen that the pattern of responses for poor readers is quite similar to the pattern for the groups of Experiment 1, with the exception of some improvement in the visual word category. Good readers, however, show dramatically increased speed of response as a result of multiple presentation in both auditory and visual word categories as predicted by the dual encoding hypothesis (Paivio, 1971), as well as in the pictorial No category.

Thus, externally available encoding possibilities are capitalized upon by the good readers, and recognition modality seems of little consequence. Poor readers, on the other hand, demonstrate particular difficulty in responding quickly to auditory stimuli and multiple input appears to be of much less utility to them than it is to the good readers.

General Discussion

Given the blind conditions of the experimentation, the present studies represent quite stringent tests of the existence of reading group differences in memory. Under this arrangement, no differences existed for single modality presentation conditions for recognition measures between good and poor readers, substantiating earlier findings of no differences in visual short-term memory (Clifton-Everest, 1974; Vellutino et al., 1975) and long-term memory (Vellutino et al., 1975) for good and poor readers, and extending them to the present classes of visual word and pictorial stimuli. The present retention interval, it should be noted, falls roughly in the range of what Bower (1975) has called intermediate term memory; thus, these findings bridge those of the earlier studies.

When the presentation of the stimuli was multimodal with recognition required in a single modality, good readers, in contrast to poor, showed significantly faster reaction times. Although the difference between good and poor readers under auditory recognition conditions (Farnham-Diggory & Gregg, 1975) is large, good reader superiority is evident in all combinations of recognition of old and new stimuli with modalities. At the same time, however, recognition frequency (e.g., Vellutino et al., 1975) does not discriminate well, if at all, between good and poor readers. In fact, poor readers' proportion of correct recognitions is at or above that of the good readers for the majority of conditions. The recognition speed differences between good and poor readers under multimodal conditions, however, are dramatically large, averaging over 300 milliseconds overall and ranging up to nearly 500 milliseconds. If reading is an interactive process involving access to and production from concepts already in memory store (e.g., Goodman, 1970; Smith, 1971), then delays of this magnitude in search and decision times could be quite devastating.

The present evidence points toward processing that is less than automatic in poor readers (LaBerge and Samuels, 1974) under certain conditions. Extra time is required to respond appropriately to both familiar and new information compared to good readers. The differences in response latency between good and poor readers exceed, of course, the general time for an eye fixation in reading, which is ordinarily in the range from 250 to 300 milliseconds. Thus, compared to the "normal" reader, one would expect extra fixations in the poor reader upon given stimuli to allow for processing to take place, a phenomenon observed and documented by early students of the reading process (Buswell, 1937). With a progressive set of fixations, short-term memory overload may occur in this fixed capacity system as new information is input but the old has not yet been completely processed. An additional problem may exist in that Averbach and Coriell (1961) have shown that after 500 milliseconds, the effect of a new visual stimulus is to erase the old in iconic storage. Thus, stimuli processed slowly or not refixated are likely to be lost.

LaBerge and Samuels have argued (1974, p. 320) that as long as word meanings are automatically processed, attention remains at the semantic level and does not need to be switched to the visual system for decoding nor to the phonological level for retrieving semantic meanings. The present data would appear to indicate that multiple-coded information is as easily accessible through one modality channel as another for good readers. This memory process appears facile and quite automatic with decision/reaction times approaching those of simple reaction time to Yes and No stimuli. In poor readers, the process is less automatic. Assuming that the reader has a relatively fixed capacity for directing reading activity and processing information, as more attention is diverted to recognition of stimuli and increasing time is required, less attention will be directed to higher level comprehension processes. Although higher processes may be available, as they appear to be in the present poor readers who have equivalent general ability with that of the good readers, they are precluded to some extent by lower level processing requirements within the system. Systematic deficits in comprehension are thus quite predictable, most likely compounded with motivational deficits as the rewards of higher order learning are quantitatively and qualitatively reduced.

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Table 1

Mean number correct and correct recognition latencies for

Yes and *No* responses in Experiment 1

	Reader Group			
	Poor		Good	
Modality/Response	Number	Latency	Number	Latency
Auditory				
Yes	3.94	2.28	3.69	2.05
No	4.69	2.45	4.86	2.23
Visual Word				
Yes	4.38	1.98	3.94	2.33
No	4.63	2.30	4.75	2.17
Pictorial				
Yes	4.56	1.82	4.68	1.73
No	4.75	2.18	4.88	2.28

Note: Presentation/interstimulus rate was 1.0/2.0 seconds.

Table 2

Mean number correct and correct recognition latencies for

Yes and No responses in Experiment 2

Modality/Response	Reader Group			
	Poor		Good	
	Number	Latency	Number	Latency
Auditory				
Yes	4.33	2.15	4.25	1.67
No	4.33	2.32	4.83	1.99
Visual Word				
Yes	4.50	1.90	4.33	1.65
No	4.75	1.97	4.75	1.67
Pictorial				
Yes	4.17	1.80	4.25	1.66
No	4.83	2.21	4.08	1.72

Footnote

[1]One potential reason for similarity of memory function between reader groups, of course, is that the standardized achievement test criteria may not identify two groups who actually differ in reading ability. As a check on the validity of the achievement test classification, teachers in the second school were presented a randomly ordered list of the paired readers who had taken part in the experiment and were asked to circle the name of the child who, in their estimation, was the better reader. If the teacher didn't know either or both children of a pair, he or she was asked not to rate the pair. Of 42 judgments about 18 pairs, 39 were in agreement with the test classification. Thus, the teacher classification very closely parallels the grouping based upon the standardized measures.