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ABSTRACT

Differences in perceptual processes of good and poor readers relevant to single word perception have been studied in a series of experiments. The major differences between good and poor readers have been shown to occur at the level of the single word; other differences occur in knowledge of spelling patterns and ability to make use of letters' positional redundancy (their tendency to occur very often in a given position) in words. To demonstrate knowledge of positional redundancy, subjects search for a target letter in a string of letters; data from experiments using this visual scanning task suggest that redundancy related to letter position alone is a strong differentiator of reading ability. Regardless of how much of the reading process is visually based and how much is based on phonology, considerable visual processing must precede a phonological stage. Other experiments have addressed a variety of topics, including brain hemispheric specialization in children's reading; differences between good and poor readers in memory processing, use of spatial redundancy, and use of distinctive letter features alone; and positional redundancy effects using novel nonalphabetic symbols. Current research is concerned with determining the relative information value of positional information alone and in conjunction with letter context information. (GW)

Final Report

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Perception and Retention in Children's Reading

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SUMMARY

Well over forty experiments were completed, not counting pilot experiments. The most important of these have been published or presented at conferences (see Appendix for a listing). Three additional large studies are in the data analysis stage; two of these are dissertations.

The intention of the project was to look for differences between children who were skilled readers and children who were poor readers with regard to (1) memory processing and (2) certain visual perceptual factors. In the first part of the project we looked for memory differences between good and poor readers in the range of grades 1 to grade 6. A wide variety of tasks was employed; the children's susceptability to proactive interference and retroactive interference was studied using both alphanumeric and non-alphanumeric stimuli (e.g., pictures, colors). No reader ability differences were discovered that could be ascribed to differences in memory storage or retrieval. When differences did occur, they appeared to be encoding differences, i.e., differences in perception.

We began to study difference in perception between good and poor readers. The differences we found appeared when single words were used and we therefore concentrated our efforts on perceptual processes relevant to single word perception/decoding. We had shown earlier (Katz & Wicklund, 1971, 1972) that good readers could detect a key target letter in a word faster than a poor reader could but the two types of readers were equally slow in detecting target letters in random letter strings. Then, Mason, in our laboratory, showed that this difference was due to the superior knowledge good readers had of orthographic regularity. It was the orthographic regularity (statistically defined) and not the meaning (or lack of meaning) of a letter string that was the important factor which determined the speed of perception.

Why do poor readers fail to learn orthographic regularity as well as good readers? Studies by Katz (1977), Katz, Mason, Wicklund & Woodward (1975), Mason, Katz & Wicklund (1975), and Mason & Katz (1977) suggested that poor readers were poorer at perceiving or encoding the relative spatial positions of letters. Thus, poor readers would necessarily be slower at finding regularities in spelling patterns and learning these regularities either visually or as they relate to the speech regularities they already knew. There is evidence that at least some poor reading is due to a deficit in learning the relative spatial ordering of nonalphabetic items. Just how much of the difference between good and poor reading can be attributed to a spatial ordering deficit is unknown (there are obviously many causes of poor reading); this is a question currently being studied.

BACKGROUND

Single word perception. This research is concerned with the development of reading in the early school grades. We are specifically interested in processes affecting the perception of single words, because it has been demonstrated that the major differences between children who are skilled readers and children who are poor readers occur at the level of the single word and not at the level of syntactic processing or the level of semantic relations among words. That is, in the majority of cases, the poor reader in the first two or three school grades has a knowledge of the grammar and meaning of the spoken language that is adequate for the reading task; it is the decoding of individual words that he finds difficult (Katz & Wicklund, 1971; Shankweiler & Liberman, 1972; Weber, 1970).

A factor found to be important to single word perception is the word's conformity to standard English spelling patterns; words or nonmeaningful word-like strings are easier to respond to if they follow standard patterns. This facilitation occurs whether the response is vocal or manual and much research demonstrates that the effect is far from completely due to a greater ease of pronounciability. The effect also occurs when the task involved depends only on visual processing rather than speech based processing or when pronounciability has been controlled (Gibson, et al., 1970; Pollatsek, et al., 1975; Thompson & Massaro, 1973).

Good/poor readers differences and spelling patterns. We find that there are major differences between children who are good readers and children who are poor readers in the way they identify the letters in a printed word. The better readers make use of their knowledge of English spelling patterns to identify some or all of the letters while the less skilled readers lack this knowledge to some degree. The greater a reader's knowledge of spelling patterns, the faster he can construct a correct perception of the printed word. We define good and poor readers as children who are at least one-half year above normative grade level in reading ability and at least one-half year below, respectively.

Definition of positional redundancy. The term spelling pattern is an imprecise one; a way of discussing regularity in printed words more precisely is to refer to the positional redundancy of the letters in a word. If a letter occurs very often in a given position in printed English it has high positional redundancy. For example, all the letters in the pseudoword "hortey" have high positional redundancy because each letter is in the position it most frequently occupies in six-letter English words. Conversely, the letters in "yterho" are all their infrequent positions for six-letter words; the entire pseudoword is said to have low positional redundancy. The real word "theory", which contains the same letters as the two pseudowords, has a summed positional frequency that is intermediate.

We can define redundancy similarly for bigram frequencies, trigram frequencies, etc. Tables of these frequencies have been generated by Mayzner & Tressalt (1965) on a sample of 20,000 English words and by us (single frequency and bigrams only) for 20,000 words from third grade reading texts. These measures give us objective indices for specifying the orthographic regularity in a stimulus word or pseudoword. In the following discussion, the terms positional redundancy, spatial redundancy, structural redundancy, and orthographic regularity are used as essentially equivalent in meaning.

Relation between reading ability and positional redundancy. Although it is clear that the child who is a good reader can utilize the orthographic regularity in a word or pseudoword better than the poor reader, it is also clear that good and poor readers do not differ when responding to stimuli which have low positional redundancy, i.e., letter strings, which are unlike regular English strings. We have demonstrated that the child who is a poor reader performs as well as the good reader in visually detecting letters in pseudowords where there is no English structure (Katz & Wicklund, 1972; Mason, 1975). However, if the pseudowords are orthographically regular a difference in detecting letters occurs. Thus, the poor reader appears to have no defects in his visual system except, perhaps, a higher-order defect related to the learning and/or utilization of visual structural redundancy.

These good/poor reader differences in the utilization of structural redundancy generalize beyond English orthographic regularity. In one experiment (Mason & Katz, 1976) children were presented with a symbol-detection task where the characters were Greek letters and mathematic symbols that were unfamiliar to the children. When positional regularity was built into the sequence of trials, the good readers were able to utilize the redundancy to decrease their detection latencies; the poor readers were as slow in this condition as they were in a low positional redundancy condition. The good and poor readers did not differ in detection latency in this latter, low redundancy, condition. Thus, these results parallel the results obtained with English orthographic redundancy: there does not appear to be any problem with the poor readers' basic ability to detect and respond to a visual stimulus; they are, however, unable to utilize positional redundancy as well as the good readers can.

This deficit may be due to a spatial-learning deficit; it appears not to be due to a more general learning deficit although further research is necessary to confirm this. In a series of recognition memory experiments (Katz, et al., 1975) we found that poor readers learned whole words from repetition (distributional redundancy, in Garner's, 1962, terminology) as well as the good readers. However, when a component of positional redundancy was added to the task, poor readers fell below good readers in recognition performance. Lastly, data from other sources support the notion that poor reading skill is related to a general deficit in serial ordering ability, which may be related to the ability to perceive, learn, and utilize information which is defined by its spatial ordering, e.g., positional redundancy (Bakker, 1972; Corkin, 1974; Mason et al., 1975). While we recognize that there are many causes of poor reading skill, we feel that there is sufficient justification to study the role of positional redundancy skill.

EXPERIMENTAL PARADIGM

Our primary experimental paradigm for studying knowledge of positional redundancy is the visual scanning task. Typically, the subject is presented with a series of successive visual stimuli on each trial. First a brief "Ready" symbol or fixation point is presented to the child followed by a single target letter, each of the two stimuli lasting one or two seconds. After a delay of zero to two seconds (900 msec typical) a horizontal string of letters appears and the subject presses one of two keys depending on whether the target letter is or is not present in the letter string. Reaction times are measured; they are typically in the range of 400-800 msec for the older children and 200 to 400 msec greater for the younger children.

The evidence suggests that the process underlying the skilled subject's response is the following. Given a target letter the skilled reader uses his knowledge of positional redundancy to direct his attention first to that position or area of the letter string where the target is likely to occur. This direction of attention is not conscious, not in awareness. If, in fact, the target is there, the search terminates and the child responds. If the target letter is not in the letter string (a catch trial) the child exhaustively searches the string and identifies the incorrect letters as he searches. (Adults may not identify the incorrect letters.) Knowledge of positional redundancy aids the skilled reader in unconsciously directing his attention to the most probable location of the target letter and in helping him to identify the incorrect letters before rejecting them. Any process which looks up printed information in memory will be made more efficient by incorporating positional redundancy into the representation of the letter or letter group in the structure of memory. If we fool the skilled reader by putting the letter where he least expects to find it, i.e., its low redundancy position, he should be slower in finding it and, indeed, this is what happens (Mason, 1975). The poor reader responds equally fast for either the high or low position of the target letter in the string.

DEFINITION OF IDENTIFICATION

By the term identification, used above, we mean that a link is made between the conglomerate of letter features which constitute the subjective iconic (or posticonic) image of a given printed letter and a symbolic representation in memory of some letter (perhaps the correct one). The symbolic representation is not necessarily the letter's verbal name and in the visual scanning task it would seem not to be. More likely, various visual representations of the initial fragmentary percept are contacted in memory. An interative process involving these and the icon constructs the final percept (if any). The final identification or percept determines the overt response the subject makes.

IMPORTANCE OF POSITIONAL REDUNDANCY SKILL.

Thus, the visual scanning paradigm appears to be a sensitive task to use in measuring a subject's positional redundancy skill. The technique can be used with English letters to assess the level of subject's acquired knowledge of English orthographic regularity or it can be used with novel, nonalphabetic characters to measure a subject's capability to utilize new orthographic regularity. We have also used a more direct method to assess the level of a subject's acquired knowledge of positional redundancy in English. Children in grade 4 were asked to choose between two stimuli: a letter in its most frequent position and a letter in its least frequent position. For each letter of the alphabet, the letter was presented alone in one of the five positions in a line of five underscores, with no other context given. Two lines were presented together, the line with the letter in its most frequent position and the line with the letter in its least frequent position. The child was asked, effectively, to choose the frequent one. The better the reader, the more often he chose the correct (high redundancy) alternative. Good readers also were more often correct with those letters that occur infrequently in all positions (e.g., b, c, p) than with those letters that occur often in all positions (e.g., e, s, t). In contrast, poor readers did not improve significantly as the stimulus letter decreased in overall frequency. From the above data, it would appear that redundancy related to letter position alone, without other context, is a strong differentiator of reading ability.

It seems to us that the skill and knowledge being tapped by our experiments are not only empirically related to reading ability but have a simple logical relation to reading ability as well. Presumably, poor readers do not easily learn spelling pattern information because they are somehow deficient in perceiving, retaining or retrieving spatial-visual regularity. Since such visual memories are an important component of reading skill, the poor reader is at a disadvantage (cf. Farnham-Diggory & Simon, 1975; Kolers, 1975).

The reader may use only visual information to access the meaning of a printed word or he may transform the visual input to a sound equivalent and then access the meaning of the word or he may run both processes in parallel. Whichever procedure is used in a child's natural reading, an important part of the process would seem to be the child's construction of a visual percept of the printed word and it is at that point that knowledge of orthographic regularity, i.e., expectancies about the spatial locations of various letters and letter groups, is helpful. By increasing the efficiency of single word perception, we not only increase the likelihood of accessing of that word's sound or meaning but also decrease the amount of time the child spends decoding the word which decreases the burden on short-term memory. This makes it easier for the reader to carry longer (perhaps complete) phrases in short-term memory and, therefore, makes it easier to extract the meaning of a phrase without as many regressive eye movements as would otherwise be the case.

How much of the reading process is visually-based and how much is based on phonology or articulation is a question of debate. Reading is generally taught by methods which emphasize spelling-to-sound correspondences (Venezky, 1970), a difficult stage to master (Perfetti & Hogaboam, 1975). Baron and Strawson (1976) present evidence that adult readers still use spelling-to-sound correspondence rules even when reading aloud familiar words; evidently, these words have not become packaged or unitized in some way as to lead more directly from print to speech. Yet Frederiksen and Kroll (1976), among others, present data which suggest that in silent reading the meaning of a word can be accessed on a purely visual basis, without going through a phonological transform to mediate the visual stimulus and the memory. Chomsky and Halle (1968) pointed out the utility of accessing the meaning of a word visually rather than phonologically. Common orthographic structure often indicates the common meaning of two words even when the phonological representations differ (e.g., sign-signal). Smith (1971) has proposed that meaning can be accessed through visual memory by using the distribution of letter features in a word and Rummelhart and Sipple (1974) have presented a sophisticated model of visual feature redundancy.

However, it is clear that subjects in an experiment can use either visual or phonological coding depending on the task demands and the subject's own preferences (Hawkins, et al., 1976). In natural reading, phonological accessing of meaning is more likely to occur the more difficult the material (requiring short-term memory) and the younger the reader (particularly if he has been taught by a "phonetic" method). But considerable visual processing must precede even a final phonological stage; some letters or feature groups must be identified, and, perhaps, some large orthographic units like syllables or morphemes must be identified and organized (cf., Spoehr & Smith, 1975). The research discussed here is aimed at this early stage of visual processing and is largely independent from the question of the mode of lexical access.

RESEARCH PROGRAM

Our research over the past eight years has applied the techniques and concepts of the information processing approach to the study of aspects of the reading process in children and adults. As indicated above, we have focused primarily (but not exclusively) on factors involved in the reading of single words in isolation. Under a grant from NICHHD (03932) from 1968 to 1971 we studied differences between good and poor readers in reading-related perceptual and short-term memory processes. Comparisons were made across different levels of reading ability and developmentally across ages ranging from kindergarten to college age subjects. Reaction time measures in visual scanning experiments showed that good and poor readers do not differ in the simple form perception aspects of the task. For example, there were no good/poor differences in scanning random letter strings which had no structural regularity (Katz & Wicklund, 1972). There were also no good/poor differences in the strictly motor portion of the task (Katz & Wicklund, 1971b). However, there were good/poor differences when children were required to visually process real words (Katz & Wicklund, 1971a; Katz & Wicklund, 1971a; Katz & Wicklund, 1973). These effects appeared to be independent of the grammatical context of the real word; scanning for a word in grammatically correct sentences was no different from scanning for a word in sentences which were ungrammatical permutations of the correct ones (Katz & Wicklund, 1971a). Supplementary work was done with adults in an attempt to illuminate the nature of the differences we obtained between real words and random letter strings (e.g., Novik & Katz, 1971). About this time, a resurgence of interest in word/nonword differences occurred in psychology (cf., Reicher's, 1969 paper). Our data and the experiments of others led us to believe that the good/poor differences we saw were centered in visual memory (e.g, the work of Posner and his associates, 1969; and later Estes, 1975; Johnston & McLelland, 1973; Pollatsek and his associates, e.g., 1975). To be sure, we understood that reading disability had many causes, but we felt that the visual scanning task seemed to be tapping one of the important sources of disability.

In the academic year 1971-72, the present writer began work at the University of Sussex on brain hemispheric specialization in children's reading (Marcel, Katz & Smith, 1973). The writer continued this work under a present grant to D. A. Wicklund from NIE (NE-G-0086). It is well known that visual-spatial tasks tend to be performed better (or controlled) by right cerebral hemisphere and that left hemisphere dominates in the performance of linguistic function. We have been looking for relations between hemispheric locus, reading ability, and orthographic regularity. This work will not be discussed further here as it is still in progress and is in any case, not directly related to this proposal.

Under the same NIE grant we looked for several kinds of memory differences between good/poor readers. We systematically examined encoding, storage, and retrieval differences using, mainly, the Peterson (1959) memory paradigm, the continuous recognition memory paradigm (Shepard & Teghtsoonian, 1961; Katz, 1966) and the PI release paradigm of Wickens (1970). These were conventional memory experiments using short and long term retention time intervals. Memory items and interpolated materials were, variously, colors, digits and letter strings which were orthographically regular, irregular or were real words. Briefly, we found <u>no</u> differences between good and poor readers in simple retrieval processes or in the stability of items in memory storage. For example, interference affected both good and poor readers equally, whether the items in memory or the items in interference were alphabetic or nonalphabetic. However, the form of what a child decided to put into memory, that is, an item's encoding, was different for good and poor readers if the item had orthographic structural regularity. For example, a shift from frequent initial bigrams (what teachers call "blends") like "br" to irregular initial bigrams like "rb" induced a change in good second grade readers' performance (in the form of release from proactive interference) but did not affect poor readers.

Poor readers were able to learn from the repetitions of an item just as well as were good readers. For example, in a continuous recognition experiment, fifth graders were presented visually with lists of 96 words, one word at a time at a rate of 4.5 secs/word. The child had to press one of two keys indicating "yes" he had seen the word before in this list or "no" it had not occurred previously. Some words were repeated at various lags for up to three repetitions. There were few errors; reaction times were measured. There were no good/poor differences in overall reaction time. Both good and poor readers strongly decreased their reaction times as repetitions increased and the words became more familiar, but there was no hint of a good/poor difference either in overall reaction time or, most importantly, in the reduction in reaction time with repetition. In a companion study, the spatial focus of presentation of the words varied. However, when a given word was repeated it always appeared in the same location as its initial presentation. When this spatial component was introduced a good/poor reader difference occurred, with good readers giving the superior performance. Details of these studies and one other are presented in Katz et al., 1975.

Mildred Mason, working in our lab, used the Mayzner & Tressalt (1965) tables of letter frequency counts to produce a metric of orthographic regularity. The tables present the frequency of occurrences of any single letter, bigram, or trigram in each serial position for each word length (from three to seven letters in length). For any given string of letters, Mason defined the summed spatial frequencies. Strings with high summed frequencies are high spatial redundancy strings. Various metrics have been developed based on single letter and bigram frequencies but the summed positional frequency measure remains the simplest and is quite effective. Using this metric she designed stimuli for experiments which demonstrated that spatial redundancy is used to augment distinctive letter features in the identification of individual letters in context and that good/poor readers differ in their utilization of spatial redundancy but not in their utilization of distinctive features alone (Mason, 1975). She was able to illuminate some particulars of the scanning process; the model of the letter scanning process discussed in the Background section is due, in part, to this work. In addition, Mason tentatively suggested that there may not be any special status for real words as opposed to pseudowords in the scanning process. Good sixth grade readers scanned high redundancy pseudowords slightly faster (though not significantly faster) than high redundancy real words. Low redundancy pseudowords were scanned relatively slowly. Poor readers were slightly faster (nonsignificantly) than good readers on low redundancy pseudowords and performed at the same level on words and pseudowords. Thus, only the good readers were sensitive to the redundancy dimension and they appeared to be unaffected by the meaning of the real words.

Mason and Katz (1976) studied positional redundancy effects using novel nonalphabetic symbols in order to eliminate the influence of the subject's experience with English print. Results from previous studies which showed a good reader superiority for orthographically regular scanning tasks could have been due to (1) a fundamental good reader superiority in detecting and utilizing any kind of spatial redundancy, alphabetic or otherwise or (2) no such fundamental good/poor difference but a good reader superiority due to the greater reading experience of good readers and, therefore, a greater chance to learn whatever spatial redundancies exist of (3) a combination of the first two possibilities i.e., a good reader has greater natural spatial redundancy ability which interacts with (perhaps determines) greater experience to produce faster scanning. The Mason and Katz study suggested that a simple experience hypotheses, the second reason, could be dismissed. In this study, the stimuli to be scanned were strings of six symbols. The symbols were initially unfamiliar to the children (fifth graders). In a low redundancy condition, all symbols appeared equally often overall and equally often in each of the six positions. When a symbol was a target symbol it was found by the child equally often in each of the six positions. In this condition, there was no good/poor reaction time difference. In a second condition, the high redundancy condition, all symbols appeared equally often overall but most symbols appeared in only one position, the remainder appearing in only two possible (adjacent) positions. The poor readers responded no differently in the high redundancy condition than they (and the good readers) had responded in the low redundancy condition. However, the good readers quickly detected the spatial regularities in the high redundancy condition and decreased their reaction times accordingly. Thus, it appears that poor readers (at least fifth graders) do not have the same fundamental skill of spatial redundancy ability as do the better readers. It appears unlikely that reading ability has influenced the spatial redundancy skill rather than the other way around, although that possibility does exist. However, there are also the studies of Corkin (1974) Katz et al. (1975), Katz (1977) and Mason et al. (1975) which make more plausible the notion of a fundamental poor reader disability in the perception of spatial ordering. The ability to encode information about the relative spatial positions of items is a prerequisite to learning spatial redundancies or patterns of regularity based on spatial positions.

Current research in our lab is concerned with determining the relative information value of positional information alone without letter context compared to the value of letter context information. Other facets of single word perception being studied are how the subject makes use of the redundancy contributed by the length of a word.

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Appendix

Research project papers published or presented to date (June 30, 1977):

Katz, L. Memory-scanning differences and picture versus word encoding for good and poor readers. Paper presented at American Psychological Association Meeting, 1973.

Katz, L. Reading ability and single letter orthographic redundancy. ~~Submitted to~~ Journal of Educational Psychology, 1977. In press.

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