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THE ANALYSIS OF READING SKILL, A PROGRAM OF BASIC AND APPLIED RESEARCH--PROJECT LITERACY REPORTS, NO. 5.

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PROVIDED IN THIS REPORT ARE COMPLETE TEXTS OF SEVERAL RESEARCH PAPERS RELATED TO THE ANALYSIS OF READING SKILL PREPARED FOR "PROJECT LITERACY." THE CENTRAL THEME OF EACH PAPER IS BASIC RESEARCH AND/OR CURRICULUM DEVELOPMENT IN AREAS OF EDUCATION RELEVANT TO THE ACQUISITION OF READING SKILLS. TITLES OF THESE PAPERS ARE (1) "EXPERIMENTS ON FOUR ASPECTS OF READING SKILL AND ITS ATTAINMENT," (2) "STUDIES FOR VARIOUS ASPECTS OF READING," (3) "THE COMPARISON OF MEDIATED PERCEPTION WITH DIRECT PERCEPTION," (4) "NOTES ON SCRIBBLING IN YOUNG CHILDREN," (5) "RELATIONSHIPS BETWEEN WRITTEN AND SPOKEN ENGLISH," AND (6) "TOWARD A GENERAL THEORY OF GRAPHIC COMMUNICATIONS--I. THE COMPONENT PERCEPTUOMOTOR SKILLS AT DIFFERENT LITERACY LEVELS." (JH)

THE ANALYSIS OF READING SKILL

A PROGRAM OF

BASIC AND APPLIED RESEARCH -- PROJECT LITERACY REPORTS, No. 5

PREFACE

The first four issues of Project Literacy Reports covered research plans that had been presented at four research planning meetings. Many of these projects are now under way and we will present their results in subsequent issues of the Reports. In this issue, a research program on reading at Cornell is described. Also, we are including the first of a three part theoretical discussion of reading by Professor Hochberg.

In December, Project Literacy will sponsor a fifth research planning conference. The research plans generated at that meeting will be reported in Project Literacy Reports Number 6 which will be circulated in January, 1966.

CONTENTS

EXPERIMENTS ON FOUR ASPECTS OF READING SKILL AND ITS ATTAINMENT

E. J. Gibson

Work has been progressing for more than five years in this laboratory on the basic psychology of reading skill. We began by asking what is reading? What is it, exactly, that the really skilled reader has learned? We made a psychological analysis of what was learned, and went on from there to fashion a theory of how this learning might progress. From such a theory, one can make predictions of behavior under various conditions for different aspects of the reading process and test them experimentally. One can also pick out what appear to be critical stages in the learning process and study them intensively under carefully controlled conditions. Individual differences in performance at critical stages will also predict variable achievement on later tests and provide another method of objective check on the theoretical analysis. These endeavors have a practical side, in addition to the goal of advancing our knowledge of the reading process, for, as one of the greatest scientists said, there is nothing so practical as a good theory.

Much of the work to date has been summarized by E. J. Gibson in an article in Science magazine. This article points out that learning to read can be roughly divided into four stages which overlap to some extent but which form a developmental sequence. They are (1) learning speech, in all its aspects such as hearing, comprehending and producing it; (2) learning to differentiate graphic symbols; (3) learning to decode graphic symbols to speech; and (4) progressive utilization of the higher order constraints and regularities in the system, the system being considered as an intermodal, graphic-phonic set of correlations. The problem of units in this system is a crucial one to which we have given much thought and toward which we hope to direct further work. Experiments have been performed with the aim of studying all four of these stages (but especially the latter three) and will be continued.

Experiments are also planned with the aim of throwing further light on the basic psychological processes underlying reading, especially perceptual learning, attention, and the detection of distinctive features, constraints, and regularities. The last year was devoted by E. J. Gibson to work on a book on perceptual learning and development, now more than half completed. The theory formulated in this book emphasizes the discovery of distinctive features, invariant relations, and structure in the stimulus. Experimental work on perceptual discovery, important as it surely is, is almost nonexistent. Experiments were begun this year on search strategy and detection with graphic materials. The experiments are developmental, comparing children in the second, fourth and sixth grades. The effects on search of background material (high and low confusion) and of multiple targets as compared with a single one are at present under study, targets in the experiments being single letters. The effect of cross-modal interference (auditory-visual) will be studied next. Individual differences as well as developmental interactions with task variables will be examined and related to IQ and, especially, reading achievement.

The program of research planned for the next several years is indicated below, in four divisions as follows: I. Research on theory and basic psychological processes; II. Research on differentiation of graphic symbols; III Research on decoding spelling patterns to sound; IV. Research on utilization of higher order constraints and rules. They will be taken up in order below, with a sample experiment or two described briefly in each instance.

Research Program

I. Theory and Basic Psychological Processes

A. Development of attention, search strategy and perceptual discovery.

The experiment mentioned above provides the model for work begun and proposed in this area. The basic question is, how does simultaneous processing of multiple stimulus inputs develop? The question has many sides. Does discovery of the target require central inhibitory processes, a "shutting out" of irrelevant stimulation? Does it matter what the irrelevant stimulation is? If so, what are the important dimensions? Evidence of the importance of visual properties of the irrelevant material, as demonstrated by their hampering effect on discovery can be considered as indications that a filtering process, separating target from background, goes on by means of a search for distinctive features and unique patterns of them. The experiment in progress is examining this possibility.

If simultaneous search for two targets, rather than one, hampers the search process impressively, it might be inferred that the process in perceptual discovery is one of holding a "schema" of the target in the forefront of attention, the search strategy being one of matching the schema to stimulus patterns. Two schemata searched for simultaneously should interfere drastically in such a strategy, since they would have to alternate. But if the search is essentially for distinctive features, the subject could follow the strategy of processing only those features held in common by the two targets which isolate them from competing stimuli. Practice with and knowledge of the feature set would be important in such a strategy, so interaction of targets and age would be expected. The prediction is now being tested.

Mediation theorists would assert that learning to name the letter gives it distinctiveness, as apart from other letters, rather than discovering distinctive features of the set and unique bundles of features within the set. If such be the case, search strategy would involve subvocal, implicit naming as the discovery process progressed. It would then be predicted that search should be hampered by the introduction of an auditory confusion background. The experiment below proposes to test this prediction.

Design. Three treatment groups will be run, one serving as a control group and two as experimental groups so as to permit comparison of the interfering effects of visual high confusion and auditory high confusion.

Group C: A control group designed to provide equal irrelevant "noise" in the visual and auditory background will furnish a baseline with which to compare the two experimental groups. There will be search for a single letter target, on a low confusion visual background, accompanied by low confusion background auditory noise (voice speaking letter names of easy confusability with target letter names).

Group E, Visual: Search for a single target, high visual confusion background, noise as in control group.

Group E, Auditory: Search for single target, high auditory confusion background, low visual confusion as in control group.

The degree of confusability of background letters will be determined by using letter confusions secured by Gibson, et al., with visual material, and those secured by Conrad (1964) for auditory confusions.

Subjects will take part in all three treatments, with order counter-balanced. Twenty trials (lists searched) will be run for each treatment. Target letter will be the same for any one treatment. Serial position of target will be randomized so as to eliminate bias for any list position.

Method. The apparatus used in the search task will be the one built for our current experiments on search strategy studying the effect of visual confusion and target number. The apparatus is adapted from one designed by Dr. Ulric Neisser (1963, 1964) including a display window for the search list (revealed by illumination when S presses a starting switch) and timing equipment (started and stopped by S). The lists are typed with a sign typewriter in the present experiments, partly because the large type was easier for children to search, and partly because this was the type analyzed for distinctive features. It will probably be retained in the projected experiment for the latter reason. Mean search time under the various conditions will be compared. Slope of the curve for search time as a function of serial position of target can be used to obtain the desired measure for each set of twenty lists for each condition and individual.

Subjects. Subjects in the first experiment will be college students drawn at random from an introductory psychology course and children who have just completed third grade.

Predicted results. It is predicted that high visual confusion will lengthen search time, in relation to the control group, more than auditory. The prediction follows from Gibson's theory of how perceptual learning occurs in the differentiation of graphemes. If this prediction should turn out to be wrong, the data will be examined for possible evidence of individual differences ("visual" vs. "auditory" types).

There is some evidence (Conrad, 1964) that numbers and letters are "stored" in memory as verbal traces, since Conrad found that errors in a memory experiment resembled the confusion errors in hearing the same items through noise. It is conceivable that storage in the adult shifts to a surrogate highly available for auditory communication. This possibility, admittedly highly speculative, receives some support from the differences found between children and adults on the Stroop test. Children will be compared with adults to determine whether there is any trend toward a relative increase in auditory as compared to visual interference in a visual letter detection task.

II. Differentiation of Graphic Symbols .

It is planned to extend the previous work of Gibson, et al. on the distinctive features of letters. A set of distinctive features for letters was worked out and tested by obtaining a confusion matrix for a set of simplified capital letters, with four-year-old children as subjects. Correlations between percent feature difference and confusions were significant for a number of letters, but both the feature list and the testing procedure were felt to require some revisions. Certain features showed up, in a multi-dimensional analysis, as clearly critical ones; others as less important and perhaps incorrectly chosen. Tests with adults, or at least semi-skilled readers, were felt to be desirable. It seemed especially important to test a feature list with material other than actual letters.

After some revision of the feature list, artificial graphemes will be designed so as to provide a set of about ten items, differing from one another in varying degrees of feature sharing. These artificial graphemes will be engraved on typewriter keys which can be fitted into an IBM machine, making it possible to type them in matrices, search lists, etc.

A. <u>Test of a set of distinctive features with artificial graphemes using a detection procedure.</u>

The search and detection method now being used in studying search behavior in children has proved to be particularly sensitive in showing up the effects of a high confusion background. It is planned, therefore, to use the artificial graphemes in a detection experiment, comparing a low-confusion with a high confusion background as predicted from the feature list. Search time should be greater, with target constant, with the predicted high confusion background.

The theory of how letter search proceeds can also be tested in this setup by comparing behavior with multiple targets when the targets, say two, share a feature which differs from all the background items and when they do not. Results from this comparison can shed light on the question of parallel processing (as Neisser favors), versus abstraction of differentiating features (as Gibson favors).

The experiment can be done with either children or adults. Processing strategy might vary with age.

III. Decoding Spelling to Sounds

As we have said before, writing is a second order code, and its patterned sequences of graphic stimuli must be decoded to speech patterns. Furthermore, a code must be learned with sufficient flexibility for the user to decode new patterns, previously unseen. A Morse code operator who could not decode a new message would clearly be of little service. Therefore, decoding must be taught for maximum transfer. How should this be done? In our earlier research program, Bishop (1964) showed that transfer occurs to new code patterns <u>only</u> when components of the code have been learned. Subjects who learned a new spelling-to-sound code by a whole word method, and <u>failed</u> to learn component correspondences within the word showed <u>no</u> transfer to reading new words, even though those words contained no new component letter-sound correspondences. Subjects who were <u>taught</u> these component correspondences did transfer; but so also did many subjects who were trained with only whole words, beacuse they discovered the individual letter-sound correspondences for themselves.

In Bishop's experiment, the component correspondences were one letter-to-one sound invariants. This is not true in English where letters may often be pronounced in several ways and spoken units may be spelled more than one way. The most useful component unit in English spelling (one which maps or decodes with relative invariance to a sound unit) is a <u>spelling pattern</u> (see, for example, Fries, 1962). Starting with the letter sequence AN, for example, one can list many consonants in front of it, e.g. - BAN, CAN, DAN, FAN, etc. and predict the pronunciation of new combinations very reliably. More complex ones demonstrate the role of environment (lists derived, for example, from AL, ALL, and ALE, so that the value of the vowel is given by the ensuing consonant cluster). But, simple or more complex, the question is how to teach these useful component patterns. Should they be taught directly, as rules? That is, A followed by LE, terminal, is pronounced ā, while A followed by LL, terminal, is pronounced ă? Few skilled adult readers could give many such rules, on request, and yet they recognize and decode new examples of invariant correspondences with ease. How did they learn the component patterns? By individual discovery and abstraction of them, as the rules of grammar appear to be learned?

The latter method seems, on the whole, preferable. Though there are rules, the people who know them don't verbalize them. And if letter-sound items were taught as components in a fragmentary way, as a "phonics" method presumably does, integration of the fragments would be necessary.

The question is one for experiment. Some alternative hypotheses must be formulated and tested under controlled conditions. Three hypotheses, at least, suggest themselves. (1) Teach component correspondences as such, integrate them later. (2) Teach whole words, in a carefully planned sequence, to promote discovery of invariant component correspondences, and test for transfer. (3) Teach by a two stage procedure of (a) discrimination by differential reinforcement followed by (b) abstraction training with presentation of items with common invariant correspondence plus a variant, test for abstraction of the concept. Two experiments are described below.

A. Learning set training for discovery of spelling patterns.

A pilot study is at present being run for this experiment. Essentially, the training consists of giving the child a long sequence of short problems, each one capable of solution by abstracting from previous items. Because it has been shown (Silberman, 1964) that this discovery process is not easy and may not occur in a short training period, it was thought that a "learning set" procedure might establish a set for transfer and promote easy decoding of new sequences.

A sample problem consists of three CVC trigrams, which may or may not be actual words but which are pronounceable in a predictable, invariant way. For example, DAB
MAD
MAB

The subject is shown the first trigram, printed in large letters on a card, told its pronunciation, and asked to pronounce it. Then he is shown the second, with pronunciation, etc. The two are then presented, in a random order, but a total of five times each, the subject being asked to anticipate the pronunciation of each. The E corrects him, or tells him the pronunciation if he cannot give it.

Then the subject is shown the third card, but he is told this time that he can figure it out for himself and encouraged to try. After 50 seconds, if he has not succeeded, E tells him the pronunciation and goes on to a new problem. The next problem begins with the last trigram, keeps the same vowel but adds a new initial consonant, as follows: MAB

NAM

NAB

The same procedure is followed as before. Each "set" of 30 problems retains the same medial vowel. There are 5 sub-sets within a set. The initial trigram in each subset of 6 problems appears once in each subset. Each test card appears twice in a subset, once as a test card and once as a practice card on the subsequent problem. Six trigrams appear only once each and are the final trigrams in each subset, offering a criterion test so that performance at the end of each subset can be compared as training continues. There are five training sets, each with a different medial vowel.* The consonant patterns in the sets are the same from one set to another, so that transfer can occur early in the set if S has achieved some abstraction of invariants from earlier sets.

As S begins to produce, spontaneously, answers for the individual problems, records will be kept of responses and reaction time. If he can anticipate training words, as training goes on, the five repetitions will be reduced. It is hoped that a few "break-throughs" may occur before the end of the first set, and that spontaneous transfer will appear earlier in each set as training continues. Learning curves can be plotted for various criteria, such as position in the set of the first transfer response; number of transfer responses in the set; and reaction time both within a set and from one set to another.

The subjects for this experiment will be kindergarten children who have not yet begun formal reading instruction. The training will be individual, and will be spread over several days, never more than one set presented in a day, and probably less. Motivation, until the child begins to transfer, is a difficulty. The present plan is to allow the child to accumulate some form of tokens which, at the end (either of each day or of the experiment) will be exchangable for a prize.

If a basic procedure for studying development of learning sets in decoding can be established, as sketched above, it will be possible at a later time to run more formal experiments with differing treatments in order to study factors which facilitate development of learning set and transfer. One factor might be preliminary practice in discriminating phonemes, before any printed material is introduced, since fair evidence exists that faulty or inmature speech discrimination greatly impedes reading, and it would be particularly apt to do so when the problem is one of abstracting letter-sound invariants.

* The problem sets for this experiment were devised by Mr. Boyce Ford, who is running the pilot study.

A second variation in the procedure might be letting the subject put the variant letters in a frame himself, to constitute the trigram. This could be done with a printing stamp, and would have two benefits; one motivational, since S is then "doing something", even before he is decoding; the other, attentional, since it makes him look at the letters and differentiate and compare them.

E. Discrimination and abstraction in learning to decode spelling patterns.

Since Silberman's study found that discovery and ensuing transfer of a simple decoding rule was not easy, at least for his subjects, who were somewhat retarded or came from culturally impoverished backgrounds, an experiment is planned to examine intensively the processes involved in "getting" the concept. Discrimination of a word, as a cross-modal spelling-to-sound unit different from others must occur, somehow. And secondly abstraction of some internal components common to several words must occur. What sort of discrimination and generalization training might promote these processes? The experiment planned will compare three treatments in a three-stage experiment. The first stage will be a discrimination task, the second a paired associate task with common elements in the pairs; and the third, a test for abstraction.

Procedure.

Group I. This group in stage 1 will learn to discriminate one word, destined to appear in stage 2, from two others which have the same first letter, but differ in the second two. The discrimination procedure will involve selecting the correct word out of the three, in a new random arrangement on a panel, in each trial. The E says the word, the S pushes a panel, causing a light to go on under the right word. The three words could be: RAN +
RUN -
RAT -

The E does not pronounce the negative instances.

In stage 2, S learns three paired associates; they are presented visually and he learns to respond vocally with the word. They will contain a common spelling pattern, as well as a variant. One is the positive stimulus in stage 1.

RAN
CAN
MAN

In stage 3, S is asked to read AN, which has never been practiced alone. Reaction time will be taken.

Group II. This group, in stage 1 (discrimination training) will learn to discriminate between three single letters, the three all to appear in a word in stage 2.

e.g. R +
A -
N -

E will give the sound of the positive letter and the procedure otherwise will be identical with group 1. The positive letter will be varied in subgroups.

Stage II and III will be the same as Group I.

Group III. This group, in stage 1, will learn to discriminate the same words destined to be learned in Stage 2.

e.g. RAN +
CAN -
MAN -

The positive word will be varied within the group. The procedure will be, in other ways, same as the other groups.

The subjects will be pre-reading children, at least 20 to a group, since individual differences are to be expected.

Results. It is predicted that Group I will perform best on the abstraction test. Even though it will have had more words introduced, and more letters, than the other two groups, the procedure provides more contrast of differences and should (according to E. Gibson's theory of perceptual learning) promote both differentiation and abstraction.

IV. Higher order units

At least as important as "mastering the code" is the progressive increase of grouping and processing components of the code in larger units. We know that structure is present in the language; syntax and meaning both create "chunks" for the perception of spoken words. In written language, there is structure to be discovered in the spelling patterns -- the spelling-to-sound correspondences some yielding simple rules and some complex ones. In the earlier research program, Gibson, Pick, Osser and Hammond (1962) showed that skilled readers have learned to use these regularities in the perception of words. quite aside from meaning. Pseudo-words following rules of English spelling-to-sound correspondence ("pronounceable" words) are perceived faster and more accurately than control words which do not. Gibson, Osser and Pick (1963) showed that simple correspondences, in short 3-letter combinations, are utilized by at least some children as early as the end of first grade, though of course the rules are not verbalized.

This research should be carried further. Much argument has been wasted on whether it is really sequential probabilities of one letter followed another, rather than correspondence rules, which facilitate word perception. The question is one for experiment. Little attention, furthermore, has been given to constraints beyond the word unit. We know, form very old experiments (e.g. Cattell, 1885) that a short sentence is perceived tachistoscopically better than disconnected words, but these experiments have not been followed up as they deserved.

A. Pronounceability and sequential probability in the word perception of deaf readers.

The experiment of Gibson, et al., comparing the perceptibility of pronounceable and unpronounceable words has been repeated by Dr. Anne Pick and a colleague with blind subjects reading braille, so that the result clearly has a certain generality. But it is far more critical to run the experiment with subjects who have never heard spoken English. In this case, there has been no opportunity to form cross-modal spelling-to-sound correspondences, except in so far as lip movements convey the same stimulus information as the speech sounds. One would expect the effect of pronounceability to be much reduced in a sample of deaf subjects, as compared to hearing ones. Opportunities for learning sequential probabilities of one letter following another are of course equal for the populations to be compared. Any facilitation of the "pronounceable" words over the "unpronounceable" words for the deaf sample ought, according to the hypothesis, to be the result of sequential probability and not spelling-to-sound correspondence.

It is true that sequential probability and pronounceability are necessarily confounded in actual spelling. In order to disentangle their effects, the data of Gibson, Pick, et al. was analyzed by correlational methods. Summed trigram frequency and summed bigram frequency for each word were correlated with perceptibility (percent correct perceptions of the word), word length, and pronounceability rating. So also were pronounceability rating and word length correlated with perceptibility. Pronounceability and perceptibility are significantly correlated (+.64) and the correlation is not reduced when word length is held constant. Trigram frequency and bigram frequency have a low positive correlation with perceptibility with word length held constant, but the correlation drops to zero when pronounceability is held constant.

It is predicted that, for the deaf population, the contribution of pronounceability should be less, and that holding it constant will result in a smaller decrease in the correlation between summed frequencies and perceptibility.

A contact has been made with a research psychologist at Gallaudet College, who will cooperate in securing as subjects deaf college students of comparable age and education to our earlier group, in order to run the experimental comparison. Equipment will be driven to Washington and subjects run, if possible, in small squads there. Since lighting and other environmental factors vary from one run of such an experiment to another, a new control group will be run if at all possible. (It may be possible to recruit subjects from George Washington U.). It would be ideal to run hearing and deaf subjects in mixed squads, with identical lighting, printed instructions only, etc.

B. Semantic and syntactic constraints in reading.

Does linguistic structure organize units for reading as well as for speech? Miller and Isard (1963) have shown that both syntactic and semantic constraints affect the auditory perception of speech. Experiments with material similar to theirs are planned to investigate grouping of word strings in reading, using tachistoscopic exposure.

The hypothesis will be tested that adding constraints, both structural and semantic, increases the length of the string which can be read in a given exposure time, and that semantic constraints (meaning) will increase in importance as the string lengthens. The latter hypothesis derives from results of one of the earlier experiments (Gibson, Bishop, Schiff and Smith, 1964) in which pronounceability had a stronger effect than meaningfulness in perceiving words tachistoscopically, but the two factors were reversed in effect when retention was measured. It is reasoned that pronounceability is a structural constraint analogous to syntax and that increasing length of a word string places more emphasis on retention, so that an interaction might be expected with meaning and length.

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STUDIES OF VARIOUS ASPECTS OF READING

Harry Levin (13)

The studies described in this section have their origins in various aspects of previous research reported in A Basic Research Program on Reading (1963), as well as experiences with observing a first grade classroom now going on under the auspices of Project Literacy. The proposed research on the learning of rules of spelling-to-sound correspondences follows from earlier studies of paired-associate learning and illustrate a different approach to some questions raised by Dr. Eleanor Gibson. The series of experiments on oral reading represent attempts to externalize the process of reading. As these studies become more complex, they will make use of a number of language measures used by the author in another research program on paralanguage in children. The final group of studies make use of data now being gathered in the course of the observation of the first grade and extend to new studies and new data.

I. Studies of Oral Reading:

Reading is a private process. The principle barriers to research on the process of reading are the lack of clear external indices to the process. Eye-movements are one such index, but the measurement of eye movements are extremely complex and fraught with difficulties of interpretation. Frequently, reading is studied by tests of speed or comprehension of what has been read. For our purposes, these measures confound the decoding and information processing subskills. We decided, therefore to take oral reading as an index which will be common to a series of experiments. The process will be inferred from the ways in which the common index varies with systematic variations in the stimulus materials. Taking such an external manifestation of reading leaves us vulnerable to the contention that reading aloud and silently involve different skills, basically. We doubt that this is true, although a firm answer must itself wait on research which compares the two modes of reading. McLatchy (1949) reports a strong relationship between oral and silent reading. We might point out, however, that developmentally, oral precedes silent reading and it is a common observation that when the materials being read are difficult, there is a tendency to mouth or to say the words.

Three studies in a projected series have been completed (Levin and Biemiller, undated; Biemiller and Levin, undated). Basically, the empirical design was to formulate reading materials of various types and to expose them to children who are in elementary schools. Initially, single words were exposed and the latency of response was measured, that is, the time from the appearance of the word to the point at which the child finally reads out the word. We plan to extend the studies to include words of various morphological forms, phrases, sentences, connected discourse longer than a sentence, etc. These studies blend, with more extensive reading materials, into the research described below, on reading in the natural, first grade situation. We anticipate, therefore, that findings from the classroom situation can be tested more precisely in the laboratory setting which will now be described, and, in turn, the experiments may help us understand the nature of reading in the classroom.

The first study* adequately describes the procedures of this research. This study was designed to test the validity of response latency as a behavioral index to reading. As such we chose stimulus materials and a range of ages which should maximize differences among groups. The subjects were children in the second, third, and fourth grades. The stimulus list consisted of eight real words and eight pseudo-words which were projected for the child. His responses were tape recorded and the tapes were analyzed by an apparatus we have devised which records the length of time between the appearance of the word and its final reading. The nature of the errors in reading are noted and analyzed.

Selected findings from this study are:

(1) Latency of response is a highly reliable measure.

(2) Younger children take longer to read words than older children.

(3) All groups take longer to read pseudo-words than real words.

(4) When frequency of errors are controlled, there are no differences in the latencies of real and nonsense words read incorrectly, but for correct responses, real words are read more quickly.

On the basis of these and similar findings we have devised a tentative theoretical formulation which helped us interpret the present findings and provided guides to subsequent studies. We hypothesize that speakers of a language store in memory auditory representations of the sounds of language. We say, for example, that a snatch of language we hear and which we do not understand "sounds like English". When the word is exposed to the child he rehearses it, more or less silently. He matches the consequences of this rehearsal to his auditory memory and emits it with varying latencies and correctness, depending on a number of factors. If he decodes to a familiar group of sounds, there is a close match between his response and his memory and the word is emitted. It is tempting to think that children read real words rapidly because they are meaningful. Our formulation makes meaningfulness one section of a general dimension of familiarity with sounds of a language.

* This and subsequent studies are being carried out in collaboration with Mr. Andrew Biemiller.

This theory, admittedly ad hoc and responsive to future data leads to the following studies which we plan to carry out:

Study 1. Variation of familiarity of sound patterns by presenting words which differ in pronounceability (Underwood and Schultz, (1960); Gibson, Osser and Pick, (1963)).

Study 2. Variations in the reading materials which increase rehearsal and the measurement of such rehearsal by a variety of means.

a. The observation of lip movements and vocalizations (observational techniques have recently been worked out by Flavell (1965)).

b. The measurement of silent speech by surface electromyography of speech muscles. These techniques were pioneered by Edfeldt (1960) in Sweden, and have recently been adapted by McGuigan, Keller and Stanton (1964) and by Hardyck (1964). In general, we plan extensive work on myography of the speech muscles during the pre-reading periods but also during silent reading and scanning.

Study 3. The interference with the rehearsal process by auditory stimulation, probably the reading of lists of words, via tape, to the child during the hypothesized rehearsal period.

Study 4. The use of contingencies in decoding words. English words may be ordered in terms of the correspondences between the spelling and sound systems. For example, many initial consonants have an invariant correspondence. Other letters and letter groups depend on their immediate environments for pronunciation (e.g., ce, ca, ge, ga, kn, gn, all in the initial position in the words. For other words, the contingency is more remote (e.g., the terminal e in mate). We will devise a list in which the words contain no, immediate, and remote contingencies. We hypothesize the latencies of reading to vary from low to high in that order.

Morphology and reading. This will probably involve a series of sub-studies. One can make several predictions about reading words which differ in morphological complexity. Consider the two words, mast and mats. Mats, carrying the plural marker, may involve two decisions, root + suffix, whereas mast only requires one; hence, longer latency in reading mats. Contrariwise, suffixes and prefixes are highly invariant in their spelling to sound correspondences so they should be readily attended to (Levin and Mearini, 1964) and decoded rapidly because they are highly practiced. The following studies are suggested:

Study 5. a. Comparison of the reading of morphologically simple versus morphologically complex words.

Study 6. b. Comparison of inflectional and derivational suffixes, under the assumption that the latter are less frequent.

Syntax Meaning and Reading. The experiments described to this point have involved the exposure of a single word and the measurement of reaction to that word. We turn now to stimulus arrays which involve more than one word, usually a phrase or a sentence. Our procedures will be of two types and these may change as we gain experience with these studies. The stimulus materials will be exposed to the child.

a. In its total form: phrase, sentence, paragraphs, etc.

b. In segments.

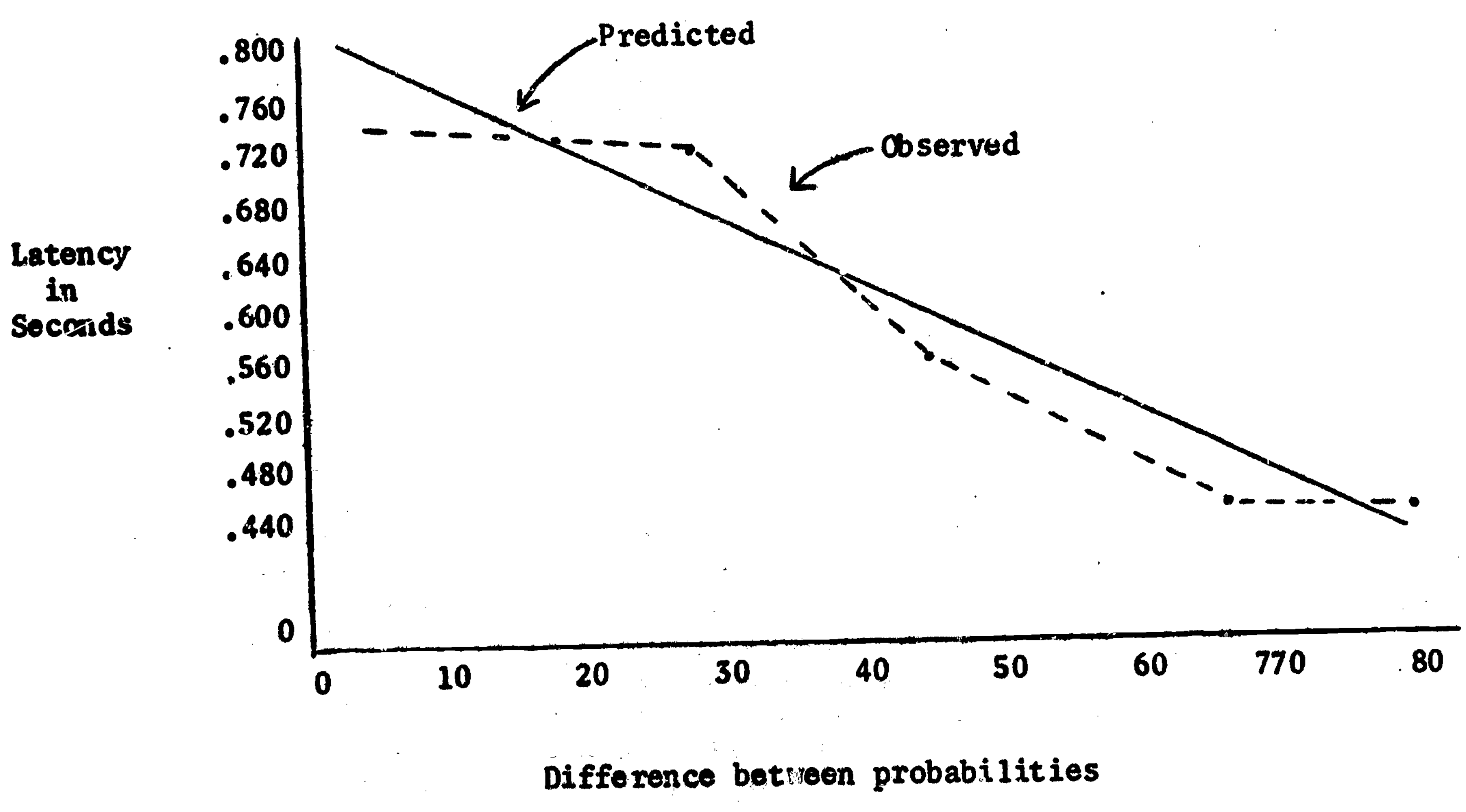
For example: The March wind blows hard, or the March wind // blows hard, or the March // wind blows hard.

The breaks in the segments will be guided by our hypotheses about reading. Generally, we have thought of reading as involving decoding of spelling to language and the processing of the decoded material. The experiments outlined above concentrate on the decoding process; the present ones emphasize the processing of the decoded materials, although decoding is certainly involved in processing. Under the more conventional rubric of "context clues", the interaction between the two processes is used in teaching children to read.

For more complex stimulus materials, the initial latency measure will be expanded to measure not only the initial pause to exposed material, but pauses and other hesitations — vocal segregates, repetitions, corrections, drawls — whenever they occur during the course of reading.

Study 7. <u>Homographs and context cues</u>.* Homographs are those words which though spelled alike, have different pronunciations and meanings; e.g., <u>tear</u>, <u>dove</u>, <u>sow</u>. These words, obviously, for correct pronunciation and for determination of meanings require more information than the homographs themselves. Consequently, homographs are ideal for studying the influence of various types of cues on the reading of the target words. Research on this problem was pioneered by Buswell in 1920.

We have found that adults take longer to read homographs than to read regular words. Further, there is an interesting relationship between latency in reading the homograph and the frequency of occurrence of the two possible forms in English. When one form is common and the other uncommon, the latency for either form is relatively brief. When the two forms occur with about equal frequency, the latency is quite long. The most obvious interpretation in the cognitive conflict engendered by two relatively equal choices is more difficult to resolve. This relationship is plotted below.



* This study is being carried out in collaboration with Mr. Boyce Ford who has carried out the pretest.

Additional studies will take the forms of adding various phonological, grammatical or meaning cues to the materials to be read to study their effects. The relation of the cues to the homograph will be important. For example, the position of the interpretive cue will give us some information about the range of scanning ahead. Consider these three sentences:

a. I read the book yesterday.

b. Yesterday, I read the book.

c. I read yesterday the book.

For the child, sentence a involves farther scanning than c, whereas b involves memory for the distinctive cue. These studies can go in many directions, based on a reasonably simple model.

Study 8. The reading of sentences which vary in grammatical complexity. The forms of the sentences may be determined by Immediate Constituents Analysis (Hockett, 1958), or by Yngve's embeddedness index (1960) or by the transformations required to form the sentence (Chomsky, 1957). Miller and McKean (1964), for example, have shown that the latency in emitting a sentence is related to the transformational complexity of the sentence. In this and the other studies in which the stimulus is more than a single word, the elements making up the sentences will be equated for frequency across variations in sentence forms.

Study 9. The violation of phrase structures. In this study, parts of the sentence will be exposed sequentially. The comparisons will be in the reading of sentences in which each segment is a phrase compared to ones in which the segments violate phrase boundaries. We expect that pause lengths and intonations will be informative about children's comprehension as a function of phrase structure.

Study 10. Syntactic and semantic anomalies. We know that in reading aloud, the visual span exceeds the point being read: The eye-voice span (Buswell, 1920). Sentences to be read will be designed so that errors in grammar or meaning occur toward the right hand parts of sentences. The pause should occur before the anomaly and the "distance" between the pause and the error will indicate the span. This distance is probably related to the materials being read, so that we predict smaller spans for difficult materials and larger spans for highly redundant materials. We also observe the pause occurring after the anomaly and we plan to investigate the conditions under which it precedes and succeeds the error.

II. The Analysis of Data Collected in a First Grade*

During the academic year, 1964-65, a psychologist and a linguist intensively observed the daily activities of a first grade in the Ithaca City School District. The regular instructional program in initial literacy, grounded in a basal reader series, was supplemented by training in hearing contrasting sound units and then in pairing these units with letters. In addition to teacher-child interaction, the teacher's method of presentation, and the children's responses to it, each child's performance in reading was noted daily, and his reading of both familiar and unfamiliar passages was recorded on tape weekly. Spontaneous speech of four selected boys and girls in various circumstances - at playtime, in dialogue with the teacher when speaking in front of the class, when dictating to the teacher - was also collected. Home interviews and standardized test scores supplemented this information. From this mass of data, three problems have been selected for intensive analysis and follow-up. Two first grade classrooms are under similar intensive observation in 1965-66 so that leads which emerge from the present analysis may be pursued.

A. The Development of Oral Reading

Weekly samples of each child's oral reading were taken from January through June. Alone or with only the investigator present, the child reads into a microphone a familiar page from his reader and an unfamiliar page with new words which he would meet during the next few days of reading instruction. The following week, this second page was the familiar one. Thus, from this corpus we can compare a child's performance over a long period of time with interlocking tasks. We also have taped records of the children reading to other members of his group with the teacher present and with the teacher absent and to the entire class.

These data permit us to analyze the changes in oral reading as the child gains competence and to relate these changes to varying situational conditions: alone, to peers, to teacher, etc.

We propose, therefore, to analyze these reading samples with the techniques of descriptive linguistics. Some of the variables which will be scored from the tapes are: pitch levels and transition contours, stress, pauses, rate and phonetic articulation.

* These studies will be done in collaboration with Dr. Rose-Marie Weber.

B. Reading and Speech Styles

Early in our observation of the first grade we noticed some changes in the speech of the children in the classroom compared to more spontaneous situations. It appeared that when children were dictating stories which would later be read, they adopted a "literary style". Their speech was similar to their oral reading, showing some of the characteristics which we expect to specify objectively on the basis of the research described in Section IIA. (above). The children's free speech in informal situations will be described linguistically and compared to speech which the child uses in answering questions on his reading or in dictating a sentence for the teacher to write on the blackboard. The differences of speech in these various situations will demonstrate the beginnings of what our tradition prescribes as educated speech. The relevant variables include those of intonation and articulation cited earlier. Also the use of morphophonemic variations and particular bookish vocabulary is pertinent.

We anticipate that the results of this analysis will lead to experiments under more controlled conditions.

C. Errors in Reading

The analyses described in this section apply to the studies described in I (above) as well as to data gathered during observations in the first grade. The reading samples on tape as well as intensive records on daily performance of every child in the class provide a sample of the kinds of errors that initial readers make at various developmental stages. Moreover, they exemplify the corrections a child may make on his own or at the teacher's prodding. After these errors are catalogued, we think that an analysis of the grammatical and semantic contexts of the errors will be profitable. The kinds of responses to written materials that are incorrect but linguistically acceptable may suggest the parameters that enter into the performances of unskilled as well as skilled readers. Likewise, they may provide the basis for determining the effectiveness of teaching words in restricted linguistic contexts as opposed to presenting them in a list.

III. The Learning of Correspondence Rules

One of the fundamental issues in experimental studies of reading is the conditions which determine the acquisition of the array of rules which govern the relationships between sound and spelling in English. A substantial part of the earlier Basic Research Program on Reading and Dr. Eleanor Gibson's experiments in this proposal concern these phenomena. Additionally, the study of rule learning in reading will have generality to language acquisition and to other behavior.

The tack we have taken before indicates that certain sequences of presentations provide the conditions for generalization of a "higher order strategy" which facilitates the learning of new instances. Specifically, we have found that the learning of two responses to the same stimulus leads to positive transfer when new instances must be learned (Ackerman and Levin, 1958; Levin and Watson, 1963a, b; Ianco, 1963; Williams, 1965). We theorized that these acquisition conditions induced a non-specific "set for diversity" which aided the subjects to learn new instances. We believe that the significant aspect of the procedures which induce this set is the opportunity to contrast the stimulus elements. Now, we plan to apply similar reasoning to an important aspect of learning to read.

Consider the words hat, fat, bat, pat. How should such an array be presented to the child so that he will learn the regularity, "the letters at in terminal position have a consistent sound"? We shall start with such simple examples but when we know how to create such learning efficiently, the results will be generalized and tested on more complex materials. We shall give a paradigmatic experiment and then discuss variations on the basic form.

We doubt that a child given the above list of words would, ipso facto, induce the at regularity. Silberman (1964), for example, found that this type of learning was extremely slow for preschool children. For one, we know that, if possible, children will identify words on the basis of initial letters (Marchbanks and Levin, 1965), so that they could learn such a list solely on the basis of the first letters. Further, to form the at concept, contrast with other instances is essential. The question we ask is: What are the optimal contrasts? The criterion is clear: when the subject meets new at instances, he must be able to apply the rule. We plan a series of discrimination learning experiments in which the major variation is the contrast of one set of regularities with another compared to the contrast of a regularity with a set of individual items. This will be clearer when we look at the following approximations of stimulus materials.

Groups

I	II	III	IV
hat-hit	hat-ham	hat-hot	hat-has
fat-fit	fat-fam	fat-fit	fat-for
bat-bit	bat-bam	bat-bet	bat-ban
pat-pit	pat-pam	pat-put	pat-pal

The subjects will be kindergarten children who will first be tested for their ability to read these words.

Procedure

The procedure for Group I will be illustrative. The two words are presented to the child and told that one is hat and the other is hit. "Point to hit". The child is reinforced for a correct choice. On the next exposure, he may be asked to point to fat, etc. The order of the list will be random from trial to trial.

Transfer tasks

Each group will have the same transfer tasks, which, at this point in our planning will be of two types.

1. Groups of words will be presented from which the children will be asked to select one.

   it up at ut am : choose at

   mat lit bar set cam : choose mat, etc.

   The initial consonants will be new and the child will have to make the choice on the basis of the terminal letters.

2. Words will be displayed to the child, one word per card, and he will be asked to "put together" all words that sound like mat, or like hit, etc. We have found the classification task useful with children.

Interpretation

We expect that positive transfer will be a function of two steps: (1) learning the general notion of regularity and (2) learning the specific regularity. On these bases, we predict better transfer scores for those groups that were trained on the contrast between two regularities. However, it should be noted that group I can form the discrimination on the basis of the medial vowel along and Group II, on the basis of the terminal consonant. The two control groups (III and IV) are included to study the course of discrimination and transfer when the above two bases of discrimination are controlled.

Subsequent Steps.

From experiments such as the above, we will refine our theoretical and empirical models. Other studies which will follow are:

1. Reading rather than pointing to words. This complicates the transfer tasks since in order to form new words the subjects must be taught initial consonants which did not appear in the training series.

2. Graphic emphasis of regularities. The letter groups will be emphasized by various means: size of type, spacing, colors, etc.

3. Guidance in formulation of rules. There is substantial and inconclusive literature on the effects of stating the rules or having the subject discover the rule at various points in the acquisition period (Haslerud and Meyers, 1958; Ervin, 1960). We will experiment with these procedures in terms of reading, which has not been previously treated.

4. More complex rules. The initial experiments will deal with reasonably simple spelling to sound correspondences. As we gain experience with these, we shall experimentally extend the model to more complex instances; e.g., the contingency of the vowel in the pronunciation of initial c; remote contingencies, as terminal e.

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THE COMPARISON OF MEDIATED PERCEPTION WITH DIRECT PERCEPTION

J. J. Gibson

Children are said to learn from images and pictures as well as from words, but this is a thoroughly muddled question in education. In order to clarify it we need a theory of the relation between the perception of things and the mediated perception of things. Mediated or indirect perception is of three common types (1) that which depends on the understanding of images and pictures, (2) that which depends on the understanding of speech, and (3) that which depends on the understanding of writing. All these can be described as perception or knowledge at second hand (Gibson 1954). Images, pictures, vocal speech and written language will here be called mediators. They are media of communication among persons. Only men communicate by these means although, of course, animals and men can also communicate by other means like cries, gestures, attitudes and grimaces, that is, by reactions that we loosely call "expressive."

Mediators, it should be noted, are not stimuli as ambient light, impinging sound, and mechanical energy are stimuli, but sources of stimulation as the objects, events, and other animals of the environment are themselves sources of stimulation. The common mediators use light and sound or, rarely, touch. It is assumed (1) that the main function of stimulation is to carry information, and (2) that information does not necessarily depend on the kind of energy that conveys it.

The hypothesis is that direct or first-hand perception is that which comes from environmental sources and that indirect or second-hand knowledge is that which comes from mediators. It is further assumed that the uniquely human media of information-transmission are of two types, iconic and symbolic. Iconic mediators have been described (e.g., Morris 1946) as "similar" to what they stand for; symbolic mediators are not. But this is not very satisfactory. I have tried to define models and pictures, the iconic mediators, as being specific to what they stand for by proportion or by projection whereas vocal speech and written language, the symbolic mediators, are specific to what they stand for by convention (Gibson 1954). The symbolic object is informative because of the establishment of a social code; the iconic object is informative by non-social laws of stimulus information. A license-plate corresponds to an automobile by virtue of conventional rules but its shadow corresponds to it by optical rules. It is here assumed that perspective geometry derives its validity from the laws of space-filling light-rays and that ideal pictorial perspective is therefore not a convention of Renaissance painters but a discovery (Gibson 1960, 1961)

The iconic and the symbolic kinds of mediation admittedly must be thought of as pure cases, not as mutually exclusive types, since many images and pictures show the influence of convention, are semi-symbolic, and many forms of writing show the influence of iconic mediation, notably graphs. The two cases are hard to separate in visual art (Gombrich, 1960). Even spoken words may in part re-present the sounds of what they stand for. Mixtures of the purely iconic and the purely symbolic relation can be accounted for by the assumption that some qualities of things and events can best be communicated by stimulus representation, by displaying, while other qualities of the world can only be conveyed by symbolic media, such as verbal propositions. Elements of both may be found in the same mediator. Both art and language are also, to be sure, mixed with elements of primitive expressive communication but this is a different question. The matter is full of difficulties, but the above assumptions at least have the virtue of being explicit.

Development of Mediated Perception

Consider the order of development of some perceptual mediators in human evolution as compared with the order in which the child learns to use them. Primitive man had to invent them; the child does not. The conventionalizing of vocal sounds may be supposed to have begun with the emergence of the human species, perhaps a million years ago. Proto-men could make and hear a variety of sounds because they were already highly vocal animals. The making of sculptures and pictures began, it is now fairly certain, some twenty or thirty thousand yeas ago in the caves of the Ice Age. This invention depended on visually guided manual skills, on making tools, fire, torches, and on the shaping of materials. Finally the invention of writing, the second-order conventionalizing of the picture-making skill so as to make the vocal symbols themselves visible and permanent, came only about five thousand years ago.

The child begins to develop the understanding and the production of speech at about the same time, at the age of one year, and does so spontaneously in a family group. Just when he begins to comprehend the iconic mediators is not clear. He is given models in the form of toys and dolls and pictures in the form of drawings and photographs (Hochberg 1962) but not much is known about what he perceives, although there is a great deal of speculation (and muddled theorizing) about the perception of forms vs. the perception of solids. More experimental evidence is needed, taking off from the hypothesis of visual stimulus information instead of the classical dogma of flat visual sensations. What evidence there is suggests that the equivalence of the optical information from an object and from a picture of it is detected early, and there is also some indication that the equivalence of small-scale models and full-scale replicas is effective. Apart from this there are no experiments on what the young child comprehends from moving picture displays or perspective transformations, despite the prevalence of television in the home. Nor is there evidence about working models. What the child learns from the unregulated gamut of iconic things presented to him is not known, although it must be important.

It is certain that the young child does not learn to produce iconic mediators, even the simplest pictures or models, until well after he can comprehend them. The necessary manipulative skill seems to lag behind the perceptual skill. However, he is usually given much practice in the fundamental graphic act of trace-making or scribbling, that is, making (and controlling) visible marks on a surface. But the perceptual value of this practice has not been studied. Similarly he is often given opportunities for plastic manipulation so as to develop his "creative" capacities but experimenters have not ventured into this field. Iconic information and iconic communication are mixed up in our culture with the concept of play as distinguished from work. Scribbling, however, is not simply play; it provides an opportunity for educating visual perception in a special way.

Finally, the child learns to read around the age of five or six and to write somewhat later. He has to detect the equivalences of alphabetic combinations to phonemic combinations (utterances) before he can do this. Sometimes it is easy; sometimes hard. The difficulty may depend on how well he has previously learned to discriminate the variables of graphic displays -- the dimensions of variations among surface-tracings.

It is likely that the order of similarity of these mediators to natural information is first the iconic, then speech, then writing. The closest approximation to first-hand experience, or knowledge by direct acquaintance is given by the first. This hypothesis should be tested. If so, images could usefully be given the child at an even younger age than is now customary.

Experiments on Mediated Perception.

It is proposed to explore some of the questions that have been raised to see what experiments are feasible.

1. Comparison of full-size replicas and scale-models. To what extent does a minified optic array, preserving ratios, carry the same information as an ordinary array for the young child? A systematic study of miniature animals, persons, objects, places, etc., should be made to determine the degree of equivalence of stimulus information.

2. Comparison of solid object, photograph, and line-drawing. Evidence on the perceptions of primates and infants is being obtained and should first be surveyed. Further experiments on the equivalence of pictures, with controlled variation, to what they portray can then be carried out.

3. Comparison of still pictures and motion pictures. There is reason to believe that perspective transformations convey information better than forms. This should be tested with young children. The perception of "animate" motions should also be studied, with a view to systematic experiments. One way to do this is to take a "still" (or a series of stills) from a motion picture shot and determine how much more information a child gets, if any, from the latter than he does from the former.

4. Analysis of the "fundamental graphic art" (tracing, scribbling) in young children. What is the nature of this special visual feedback and what is learned from seeing a permanent trace being made? At what age do children begin to see Michotte's "tracage" effect (1964)? A separate note has been written on possible experiments to answer these questions and is appended.

5. Tests of the hypothesis that environmental information may cut across perceptual systems (cross-modal information). The present approach is based on the idea that stimulation, although necessary, is less relevant for perception than information. The equivalence of information across different media of communication is fairly well accepted. But the equivalence of information across stimulus energies is a new idea that needs verification. It can be tested in various ways, for example by determining the extent to which young children can equate the visual appearance of an unfamiliar texture with the tactual feel of it. Cross-modal equivalence can also be tested with solid shapes previously unknown to the child.

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J. J. Gibson

I do not believe that the important fact about "scribbling" is the kinesthetic feedback (the joint and muscle reafferents) but the visual feedback and its outcome.

This visual feedback might be called an elongating trace (cf. Michotte's recent experiments on what he calls tracage). It is progressive in time and the outcome is a frozen record of the movement of the tracing tool (and the hand). It occurs with a finger on any soft surface (or a dirty finger on a clean surface, as every mother knows). This is not yet drawing, nor even self-expression, but only the recording of a movement. The movement may be random but the trace of the movement is not. This is why I call it the fundamental graphic act. One necessarily gets a visual perception of form after having a visual and haptic experience of movement.

Now this visual perception of a line or form is more than the seeing or the feeling of movement. It is not "kinesthesis." If it were only that, the child would get it simply from watching his hand move. A child will not scribble with a non-marking crayon, to my observation (but this experiment needs to be done systematically). The graphic act yields a permanent record of a movement. More exactly, it converts a path in time into a form in space. It is not a visual motor coordination or association of sensations nor is it a proprioceptive feedback, since it creates something visible, although this is not yet an image, drawing or representation.

It has many forms (tracing, smearing, daubing, scratching, grooving, painting, drawing, writing) and it is found in other primates than [illegible] cave men and the modern infant. My tentative definition of the fundamental graphic act is a permanent change in the reflecting capacity of a surface that is progressive in time, the progress of the change being perfectly correlated with a displacement of the hand. The sensory feedbacks from vocalizing, locomoting, manipulating, and behaving in general are ephemeral, but this kind of feedback produces something lasting. Graphic activity should not be confused with motor activity.

The discovery by the young child (and by the cave painters) of the optical equivalence between traces on a surface and the edges of real objects in the environment comes later. Only then does the magic of representation become possible. (It is easier for the child than it was for primitive man because the child is shown graphic displays and pictures long before he can make them.) But this discovery, that something not on the paper can be there - a virtual object - has great consequences for the development of perception.

The fundamental graphic act is similar to what might be called the plastic act (modelling) and to others like breaking, tearing, taking apart, fitting together, or even moving something from place to place. All these produce an optical transformation that specifies a change of the environment and the latter produce a haptic change as well as an optical one.

The graphic act, as the term implies, is prerequisite to both writing and drawing. But learning to put words on paper is radically different from learning to put things on paper (objects, persons, places, events). The common basis, however, may be the cause of the confusion between writing and representing that we seem to fall into, and also the cause of the ancient but wooly notion that we can put "forms" on paper.

Experiments

1. Will a child lose interest in manipulating a tracing tool when it ceases to leave a trace?

2. How old must a child be before he will pretend to draw or write in the air with a tracing tool? The visual and the motor kinesthesis, the feedback from eye and hand, are identical (except for the pressure feedback) but the graphic product is eliminated.

3. Will a child perceive something that makes a trace when a line elongates on a blank screen? How young will he see it as thus caused?

4. How much disruption of the graphic act occurs with right-left reversing spectacles?

5. At what age will a child attempt to make a line that coincides with an existing line (to "trace" in another meaning of the term)?

6. At what age will children, when asked to draw something, behave differently when the object is present than when it is absent?

7. At what age can they be made to understand the optical trick of tracing edges with outlines on a sheet of glass? If this is quite late, as I suspect, it is not consistent with the accepted visual theory of sensations.

RELATIONSHIPS BETWEEN WRITTEN AND SPOKEN ENGLISH

Charles F. Hockett

The research currently being conducted under my direction, almost wholly by Daniel S. Kimball, is based on the following assumption: (a) English written words are not a simple and direct representation of spoken words, since there are too many cases in which the spelling is not predictable from the pronunciation (REED and READ, DISCRETE and DISCREET, and so on). (b) English spoken words are not a simple and direct representation of written words, since there are too many cases in which the pronunciation is not predictable from the spelling (e.g., BOW, LOW, SOW, PERMIT, INVALID, ARITHMETIC, UNIONIZED). (c) We may therefore seek a kind of representation--a "spelling" using an alphabet of characters that we devise for the purpose--from which both the actual spelling of the written word and the actual pronunciation of the spoken word are completely predictable. (d) Having achieved such a representation, we can speculate that in some sense (certainly a "black box" sense rather than a neurophysiological one) the literate speaker of English has this type of representation inside his head: that sentences are generated in the first instance as strings of this spelling-speaking-indifferent type, and then mapped into the written form or the spoken form as circumstances require. (e) If so, then the acquisition of literacy in English is not merely the acquisition of spelling-to-sound and sound-to-spelling rules, but involves the building-in of this additional, implicit, level of representation.

The work done so far has been directed towards a formulation of a suitable alphabet (of characters we call "morphons") for this additional inner level of representation, together with the detailed morphon-to-letter and morphon-to-phoneme functions. The statistically most prominent and important features will have been discovered by the end of this academic year, and will have been reported at least by t the end of the summer in the form of Kimball's Masters Thesis. But this will leave many problems, for which the first integrated presentation forms only a coherent frame of reference:

(1) Which of several formal ways of setting forth the morphon-to-letter and morphon-to-phoneme functions is preferable?

(2) How do we handle very rare irregularities? (For example, do we set up a morphon A_{17} for the form $M_1A_{17}N_1$, which, when this is the whole string, yields spelling MAN and pronunciation /mæn/ but, when followed by a morphon S_2 yields spelling MEN and pronunciation /men/--the S_2 disappearing here, though more often it appears as graphic [illegible]?) [illegible] are not yet sure even of the principles which should guide our choice of alternative procedures for such cases.

(3) If this new characterization of the relation of written English is closer to the truth than the older linguistic assumption that writing "merely represented" speech, then what is the proper ordering of pedagogical materials for the child who is to be guided to literacy? Do Bloomfield's principles of pedagogical ordering survive the change of frame of reference? If not, how must they be modified?

(4) Relevant for the preceding: how drastically different are: (a) the internal "morphon" representation of English if an illiterate adult or a preliterate child, and (b) the same "morphon" representation after the acquisition of literacy? Does the acquisition of literacy perhaps affect even more radical and deeper restructurings of the individual's language habits?

(5) We have developed (at Cornell and elsewhere--this is an inclusive "we") computer programs for the efficient tabulation of spelling-to-sound and sound-to-spelling correlations. Can these programs be adapted to give us help in seeking the details of the morphon-to-letter and morphon-to-phoneme functions?

As is obvious, these problems (and the list is not exhaustive) imply collaborative work, in the long run, among specialists in a number of disciplines: linguistics, learning psychology, mathematics, computer science. The purpose of this statement is to indicate approximately how far we have gotten so far and how much still remains to be done.

Toward a General Theory of Graphic Communication: I. The Component Perceptuomotor Skills at Different Literacy Levels

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Abstract: A program of systematic successive adjacent fixation, such as required in reading letter by letter, is, it is argued, difficult and inefficient to sustain, and sampling procedures are soon learned by which the eye, subject to peripheral search guidance (PSG) and cognitive search guidance (CSG), makes large-scale excursions seeking information at those points at which a knowledge of the structure of language, and hypotheses about the text's meaning, lead the reader to expect information to be found. Since such knowledge varies with practice, so should reading patterns.

Introduction and outline

This paper is concerned with the activities by which information is retrieved from graphic material. The speculations contained herein are the results of discussions with Harry Levin and Virginia Brooks (who are, however, not necessarily in agreement with any or all of them) and a number of preliminary experiments. Where other collaborators are not specifically mentioned by name, the research was performed with the assistance of Virginia Brooks, usually with from four to six children as subjects. Both the theoretical treatment and the experimental procedures and results will be presented in greater detail after the latter have been replicated with larger numbers of subjects.

This inquiry proceeded in three parts, one of which is presented here. In this first part, we shall consider some of the component perceptuomotor skills which would seem to be involved in the acquisition and development of literacy. In the second part, I intend to discuss the ways in which picture-text combinations might be perused and used by readers of different ages and degrees of literacy. In the third, I shall attempt an analysis of the conditions contributing to the acquisition and maintainance of desires to read — i.e., the conditions of effective literacy.

I. Perception as a serial product of looking behavior.

Since our eyes register fine detail only within a small central region of the visual field, we can learn about the wide world that confronts us only by successive glances in different directions. Because the integration of these serial glimpses into a single, apparently stable perceived world, with fine detail apparently equally distributed throughout, is usually so good and because the world we see normally contains no hint of the continual changes of retinal image that occur as the eye sweeps the world confronting it, the psychologist can often ignore the sequential nature of the sensory input and chose some more constant features of the outer environment (the distal world) as the starting point for causal analyses of the perceptual process.

Where one is concerned with looking behaviors per se, of course, this simplification is impossible. Especially in the case of the reading process, where a definite spatial order of graphic symbols must be detected in order to reconstruct a definite temporal order of language, the fragmentary nature of the single glance, the nature and determinants of the succession of glances, and the rules by which the contents of successive glances are integrated into a single perceptual structure, are very unlikely to be matters which can be disregarded with impunity. First, I shall outline some of the plausible determinants of looking behaviors. Next, I shall consider how these determinants might affect the activities of apprehending the visual world, of perusing pictures, and of reading printed text, at different stages of the development of these various abilities.

A. Programming glances.

1. The necessity of conjoint storage of shapes and distal addresses.

In order to put together the information obtained by the eye in successive glances, the relative directions of the eye during each glance, the order in which the glances occur, and the station point of the head and body as a platform for the eye throughout all these glances — the effects of all of these must be taken into account by the integrating mechanisms of the visual system, or the information obtained at any moment would be essentially useless.

Thus, if we fixate in turn each of three points or letters, A, B, C, the reader must be able to register and to store both the visual data about shape gained in each of the fixations, and about the shapes' locations in outer space — i.e., their "distal addresses" — if he is to perceive the spatial array as ABC rather than CBA, etc. Thus, the shape's distal address is a hypothetical construct, whose nature is deduced by the psychologist from the way in which that shape is integrated with other shapes (i.e., a distal address need not be correlated with, or accompanied by, any experience of apparent direction about which the subject can report independently). The subject must also be able to treat as completely equivalent the various different sequences of successive glances by which he arrives at a given distal address, so that regardless of how his eye arrives at a given fixation point, and regardless of the position of that fixation point relative to the shape to which some distal address must be assigned, the same spatial array is perceived. Note that this is a perceptual ability which must be learned very early in dealing with the world, but which must be superseded when the organism, much later in life, takes to reading.

Since eyemovements are much faster than headmovements, the observer's gaze almost certainly traverses any interesting region more than once before some head movement changes the field of vision; because the number of points of possible interest into which any visual field can potentially be divided is very large (say, at least 250,000, for even a single foot square region at a two foot distance, judging by the size of the last two years' models of portable TV receivers); because that number is much larger than the number of pause-points in any scene which are likely to be informative or interesting; because we can't expect the interesting objects and regions always to be in the same places relative to the eye (i.e., in the same visual direction), in each possible stimulus display; and because if we add to the previous considerations the fact that we have clear vision for small details to about 4 degrees distance from the fixation point (and for progressively coarse details as we go for considerable distances away from the fixation point), the eye will probably pass within seeing distance of quite a few of the interesting distal addresses several times during quite different courses of investigation of any display; — for all of these reasons, the eye will have to undertake what must appear to be an unsystematic sampling of all of the possible paths by which it might traverse any display. The actual search path must be contingent on the particular stimulus display, if any economy of glance is to be achieved. That is, the alternative to a systematic scanning raster, which must be uneconomical for the reasons outlined briefly above, is to use a contingent selection of possible fixations — a selection and sequence of fixations that is guided by the distributions of information within any given visual display. Now such guidance can be only of two kinds, as far as I can see:

a. The low-acuity information picked up in the periphery of the eye (and to some extent, the high-acuity information picked up by the nondominant eye if convergence-fixation is not perfectly maintained) can suggest to the optic search system where it must move its point of clearest vision in order to get an informative, clear view of some potentially-interesting region: i.e., peripheral search guidance (PSG).

b. The previously gained information (gained nonvisually as well as visually) can provide "search hypotheses" as to where one should look, i.e., knowledge about what one has seen so far within a display should provide some guesses about where one should look in order to obtain further information; i.e., cognitive search guidance (CSG). (Note: I am not talking about "real" or consciously-reportable hypotheses here: these, too, are constructs, and I only use the words "hypotheses" and "cognitive" because I can't think of better ones.)

I shall argue that reading, as a perceptuomotor task, requires us to use both of these, if the task is to be performed with any efficiency, and I shall describe some pilot studies which attempt to test these visual search skills at different stages in their development.

Note that the spatial framework within which a distal address is assigned to any given shape by the visual nervous system need not be at rest with respect to the observer (e.g., the various points on a sheet of paper which is itself in random and rapid short-excursion movement, are nevertheless assigned to fixed and rigid distal addresses on that paper, at least in some circumstances). This point is sufficient to distinguish that property of a shape that I am here calling its distal address, from the more usually employed term of visual direction.

Since such complex directional registration and storage is a requirement of visual perception in general, we should expect to find the implied visuomotor ability to be highly developed even in early childhood. This set of skills is certainly implicated in all looking. Even the word on the printed page, which must be decoded in fixed sequence, must be taken to be the same word, regardless of the path by which it comes to be fixated. However, there is nothing at all in this posited ability, as we have discussed it so far, which should make it possible for a subject to follow a systematic scanning of space over time, or to keep precise track of the order in which any search course has been traversed after integration has been completed. That is, we have no reason to ascribe to these skills, when fully developed, the ability to follow a systematic mapping of spatial order into temporal sequence.

This argument does imply a system of perceptually-guided surveying movements, with the particular sequence of glances in any survey being determined jointly by the nature of the search task, by the nature of the stimulus distribution, and by where each individual observer starts his initial survey of any display. There may, of course, be characteristic directions of attack (e.g., top-to-bottom of any piece of paper, or left-to-right) within which the initial stages of the survey proceeds, either by actual eyemovements or by some hypothesized post-retinal scanning processes (cf. Ghent; Harcum; McFarland), although most of the present evidence to this point is as easily interpreted as a matter of "readout" from "storage" as it is of visuomotor or central analysis. However, these directional biases could not, in general, prescribe actual sequences of fixation in unfamiliar displays if anything like a reasonable economy of perusal of the world is to be achieved.

We should therefore expect looking patterns recorded during inspection of normal visual displays to be characteristically unsystematic (and the more so, the more naturally redundant the material and the better the seeing, since as these improve, there are a greater number of fixations which are equivalent in the sense that they pick up the same predictive content from the display). Looking patterns should then vary in the sequence with which various points in the display are fixated, from one observer to the next and perhaps from one time of perusal to the next and so they seem to. However, since the number of points of informational value are fixed by the display, as well as by the observer's pattern of CSG, we should expect that the general selection of regions that will be fixated in any given display will be similar (when grouped into sectors of about twice foveal diameter, or about 8 degrees) from one observer to the next (and this also seems to be the case).

<u>2. The scale of saccads in the normal visual environment.</u>

I know of no studies in which eyemovements were recorded, without the subjects' knowledge, in normal environments (in fact, I don't know how this can be done without fettering the head and trunk in an exquisitely unnatural manner). However, it seems reasonable to believe, on the basis of the ways in which people regard pictures under covert recording conditions, and on the basis of the previous analysis of what has to be done in order to search any unfamiliar scene, that something like this must occur:

First, the major likely informative points of the scene are scanned, probably with as much gathered from one position of head and trunk as possible (i.e., with as small a ratio of head movements to eye-movements as possible); then, where small detail is needed to determine some aspect of the scene's meaning, saccads will bring the regions of detail to the fovea, followed by whatever small excursions the elucidating of the detail may demand. What this amounts to in the way of saccads is a high ratio of large saccads to small ones, with successively finer or more detailed expectatians being tested and confirmed or disconfirmed, up to the limits dictated by task and by stimulus display. The mechanism for keeping track of distal addresses over large excursions should be well practiced; the mechanism for keeping track of small, sequential excursions, need not be. Let us see how these compare with the skills demanded by reading.

3. a. Specific requirements of reading.

The first new task introduced by reading is the necessity of translating spatial into temporal order. I shall here assume that the reader is learning to put together groups of one or two letters into the sequences comprised by words. (Whether or not the reader actually learns this way, or by some more "molar" method of instruction seems to me to be largely (but not wholly) immaterial, since sooner or later he must proceed with this kind of analysis or lose most of the advantages of both our alphabet and of Gutenberg's discovery: moreover, even if the reader started with a visual vocabulary in which each word had been learned as a unique pattern, he would still have to read those words in succession, and to put together successive glances necessitated by words longer than could be encompassed in a single glance.) I am going to assume that, at least because it runs counter to the normal demands which the visual environment has placed on the oculomotor system's development (or because such movements are innately hard to execute and to assign appropriate distal addresses to), such sequential small movements are very difficult. Common usage has it that children need to learn with large letters and words because these are easier to discriminate. If we ask why these are easier to discriminate, the answer can certainly not come in terms of visual acuity: the clarity of vision enjoyed by a six year old is more than adequate for the task of reading, and more than the equal of the skilled forty year old reader. My explanation (which of course is not the only one possible) is that if it is in fact true that larger letters are easier for beginning readers (and indeed what I am arguing is that formal experimental test would reveal it to be true), then this is at least in part due to the difficulties in hobbling the eyes to shorter and systematically sequential saccades. I specify beginning readers because one or both of two changes would relieve this difficulty: In practiced readers, such hobbling might become sufficiently more skilled that it no longer comprises a hard perceptuomotor chore. Alternatively (or perhaps additionally), as we shall see, the advanced reader needs much less in the way of short saccades and more in the way of ballistic movements of relatively long sweep, with extents and termini set by PSG and CSG. That is, the practiced reader learns to sample a page of text, rather than "read it" in the strict sense of the term, in ways much closer to those used in sampling pictures and objects, and is thereby returned to a longer span between eyemovements. Reading is a process closer to an open-ended expectancy-testing rather than a decoding of strings of symbols.

b. Recognizing previously-entered material.

Part of the problem of integrating successive glances into a single perceived structure consists in the recognition that a given shape is not a new one, but is one already noted at the same distal address (or perhaps an already noted shape which has moved to a new address, but in any case is the same, single shape, not a second instance of that shape). The first time an entry of contour or shape is made at some distal address, its presence must be noted and incorporated into some listing or structure. The next time, it must be recognized as having been previously entered: it is then confirmatory rather than informative. (I shall argue in a later paper, Part III, that an unconfirmed or partially-confirmed perceptual expectation has motivational properties of great practical and theoretical consequences, a position that is by no means novel but which is almost completely unexploited.) There are several ways in which this might be done: for example, motoric proprioception (by oculomotor kinesthesis, or by the presently more widely accepted possibilities offered by "recorded" exafference), by visual proprioception (i.e., by "recorded" reafference), or by some form of "pursuit". I shall here assume that the primary determinant is the last: some visual kind of record is kept, and that this visual record is the most important set of determinants of the distal address and, therefore, of the eyemovements which scan the letters. This assumption is made here not because of the kinds of evidence obtained from physiological or sensory investigation (since the wide discrepancy between the complexities of stimulation available in the normal reading situation and the paucities of such cues that can be drawn upon in the situations in which the sensory research is usually pursued (and in which distal address and visual direction are usually identical) might well carry with it a discrepancy in the bases for determining distal address), but because of two kinds of observations that are easy to make but which have not been formally tested:

The first is this:

> I find it particularly difficult to detect errors in copy when those errors consist of either the addition of a third letter to a word already containing two of the same letters, or the repetition of a word in a sentence.

The second is:

> If I hold a piece of paper at eighteen inches, each space between words subtends about ten minutes of visual arc; if I move the paper back and forth so that it moves that amount or more between the time at which I first read a word and retrace it, or go on to the next letter (or even the next word), I find little or no difficulty in reading the material.

Now, even if the sequence of fixations were tagged by motoric proprioception of some sort, there would have to be a reasonably precise registration by the visual system of the purely-visually-given-notion of the entire piece of paper in order to assign the motoric signs of direction their appropriate meaning — and, if that is so, the visual registration of distal address must be sufficient, by itself, to maintain reading as a skill. This argument is of course, far from conclusive, even if it were based on formal evidence instead of armchair observation, but I shall present some better support below, and in any case I am proposing a very tentative scheme, not arguing as yet that that scheme is valid.

This problem of recognition of previously-entered material as being previously entered, appears again in two other aspects of the reading process.

The first, is the ability — essential in reading normally dense text — of maintaining the sequence presented within a single line of type, and of starting the next line after having finished with the first one. The second, is the ability to recognize that one has already read the page one starts, accidentally, to reread. I think that these involve two very different kinds of processes, and I shall discuss the second one in Part III. The first — maintaining the linear sequence — is directly relevant to the problems discussed in this section, and can tell us something about the determinants and precision of PSG.

c. Maintaining linear sequence: a demonstration of peripheral search guidance.

When I have finished reading a line of type, I must commence the next one in sequence by returning what may be a distance of about 25 degrees to the left and dropping to the next line, a distance which may be as little as 0.25 degrees; i.e., executing a change of distal address of about 1.0%. There are three mechanisms that immediately suggest themselves as being responsible for the maintenance of this ability:

The first, is some sort of motoric proprioception, i.e., maintaining an absolute egocentric spatial framework within which this set of movements can be executed. This seems unlikely to be an important factor because of the relatively poor ability to fixate a selected point at which no visual stimulus appears, because it seems to be true that a subject can continue to read from line to line, with little or no loss in reading speed, even if the piece of paper being read is moved rapidly up and down with a movement of the order of 0.25 degrees or greater (so that in the period in which the eye leaves the right-hand side of the page and travels to the left hand side, the lines of type have moved into new positions on the vertical axis). This is a matter of casual observation, and formal research is needed to determine whether or not this is indeed the case.

A second alternative is that the sequential progression from line to line is maintained by the recognition of meaning — i.e., by cognitive search guidance in the sense that you recognize either that you have read the line before, if you don't drop down far enough, or that it fails to continue the sense of what you have been reading, if you drop down too far. This also seems unlikely to be an important factor (although it certainly must contribute something, in normal reading) because of the following series of pilot experiments (about which I should caution that they were executed with no more than one or two subjects and without formal control procedures, and therefore should be considered primarily as illustrations of how the various possible component skills in reading might be dissected).

If a piece of copy of about 10-15 lines is so prepared that the first 25 characters are identical from one line to the next (this is not hard to do, although it makes for some pretty peculiar prose), a subject progressing from the end of the 7th line to the beginning of the 8th line can't tell by the contents of the foveal view received at his first fixation point whether or not he has advanced a line. There should, in consequence, be a great deal more error (and/or it should take much longer) in reading this copy than in reading exactly the same copy but with the format so altered that the left-hand ends are no longer the same from line to line. I have found no such marked difference between the two kinds of copy, even when they are both set into the same kind of motion that we considered above. If in such copy, made up of lines which are identical for the first 25 characters, we now make the subsequent set of 15 characters identical on alternate lines, the subject now encounters no new material until he is half-way across the page; he is still not appreciably bothered (although he reports that he is not sure that he is on the right line until he encounters the new material). If in fact we were dealing with CSG in matters of line maintenance, we would expect this kind of doctoring of the text to be crippling.

The only ways in which I have been able to disrupt drastically the ability to start the next line are these:

a. By altering the spacing so that in terms of proximity as a grouping factor, the letters are closer together vertically than they are horizontally i.e. the type appears to be arranged in columns rather than in rows.

b. By having the subject read through a vertical slip — a sort of narrow, clear lorgnette surrounded by two opaque masking bands — which he moves across the page. If the two opaque masking bands are no wider than a couple of letters, this does not interfere with the subjects' finding the next line correctly, (even if it is in the copy in which the first 25 characters are the same on each line). However, if the two masking bands are each ten characters or more in width, there is an abrupt increase in the number of errors of line identification.

As I have said, these experiments have to be repeated with more subjects and under more formal conditions before any conclusions can be offered. But they do suggest the exercise of the periphery in this respect of guiding search patters: the eye appears to be capable of maintaining its position on a line of type (or, more probably, of maintaining the distal address of a line of type) in terms of information entered from the periphery; perhaps the mechanism is one of detecting whether the same retinal region remains stimulated by the members of a horizontal band of type as the eye moves to the left and the type moves over the retina.

Let us assume, then, that such peripheral search guidance exists.

How could it be used to guide a sampling procedure by which contingent search patterns of eyemovement could be executed, av.oing the necessity of reading letter by letter in a sample of textual material?

B. Sampling and graphic redundancy.

In order for sampling to be possible -- in order for anything less than step by step reading of each letter, word and phrase in a passage of type to suffice -- some degree of redundancy must be present.

Now, in fact, redundancy is impressively great in printed English. Resistance to spelling reform has been attributed to the fact that redundancy is pretty close to 100% (in the middle of long sentences) with the present spelling and syntax. But redundancy has virtues only in conditions of transmission which are "noisy" in some sense -- conditions in which parts of the message are likely to be lost. Why do we need redundancy in printed English? What is the noise? Why should part of the message be lost, with good type on white paper in decent light?

Because, I am arguing, it is hard to make small and systematic saccads, and because it is easy and rewarding to make great swoops and guesses which are confirmed -- to sample as lightly as possible here and there in the text, putting the pieces together from as little actual reading as possible. In short, orthographic redundancy - even the awkward forms taken in English, which may be driven to these because of the lowered syntactical redundancy that goes with our fragmentary grammar and absence of genders (I am here suggesting that the price of a weak and irregular grammar is to have an atrocious orthography) -- orthographic redundancy is the adult's substitute for large type. But it is also more than that: the length of a word, or of a phrase, or of even a paragraph -- these are informative, and unlike a mere enlarging of letters, which permits the eye to make large excursions, the use of spelling which can be sampled at strategic places provides information to the periphery of the eye in the rapid perusal of a block of type.

This is why redundancy is of value, and why we don't simply remove it and save space.

This is why it appears as though really skilled readers are processing a tremendous amount of information per second -- they're not: they merely know more about the language (its syntax and cliches), about writers, and about the world, so that they need sample less frequently and their hypotheses pay off more regularly.

This is why newspapers, and other densely packed material, divide their pages into several columns -- to provide anchorage points to which to refer the sampling procedure and with which to obtain the line sequence maintenance.

If this is right, normal practiced reading is an active process, involving the continual generation and testing of hypotheses, not an almost automatic sequential decoding process. On the other hand, it should also be an extremely variable process, depending on the task of the reader (i.e., what he is reading for), on his knowledge of the language and its contingencies and on his knowledge of the world about which that language is talking. Thus, receiving instructions to read aloud would change the pattern of search, in the mature reader, forcing him to do much closer sampling (i.e., instead of picking up only, say, the beginning of every long word and of all capitalized words, he would have to sample at least the beginning of most words), while instructions to find spelling errors would change the nature of his task entirely. Since such differences in recorded eyemovements with task have indeed been reported by Judd and Buswell, the question of the implicit instructions in any reading experiment become particularly important (e.g., one must interpret very cautiously the results of any procedure in which the subject knows that eyemovements are being recorded — indeed, that the experiment involves the quality of his reading as an integral variable).

Reading, then, is a gross name for many different kinds of activity, sustained by different goals and mediated by different kinds of sampling strategies.

In general, it is expected that the longer-span search tasks, involving expectancies which may not be confirmed for periods of paragraphs or even pages, would provide the main impetus to continuing reading a given book; this kind of expectancy demands knowledge about the world, is clearly dominated by cognitive search guidance, and makes most demands on sophistication about the subject-matter and least on knowledge about orthographic and syntactic redundancies. We shall consider possible rules governing such long-span CSGs in a later paper (Part III). However, short-term CSGs, exercised within sentences and even within words, demand knowledge about the language: the reader can't sample economically unless he can fill in the blanks between the points sampled (at least, unless he can fill them in in the sense that he can proceed to further sampling on the basis of previous fixations — this is an important point, because it predicts that the correlation between good reading speed and good spelling ability need not be particularly high, as long as the criterion of having "filled in" correctly is that the good reader can correctly anticipate where he should sample next and what, in terms of meaning, he will find). This kind of redundancy and format should contribute to the maintainence of an easy flow of reading, being roughly what is called style, but the criterion will again depend on the habits and sophistication of the reader as much as on that of the writer. (I have not thought through the implications of this argument for the various attempts at improving reading ease by age-level-dependent formulas, but it would seem to have such.)

But we should also note that this kind of stylistic maintenance of reading cannot proceed under CSG alone:

If the reader is to know where to sample, in a sentence or in a word, in order to obtain information needed to continue reading, he must have some degree of guidance from the stimulus display, that is, there must be some degree of peripheral search guidance involved in the maintenance of cognitive search guidance, in the practiced reader. Let us see now what kinds of redundancy might be sampled on the basis of such PSG, and how it would probably vary at different stages of sophistication of the reader.

1. Peripheral search guidance and orthographic and syntactic redundancy.

The first letter sampled in any word, taken completoly out of context, carries the maximum amount of information; to the extent that there are any orthographic constraints, any constraints based on syntax, constraints imposed by the meaning of the previously-read text (and by that of any pictorial context which might be provided) — to the degree that each of these contingencies reduces the uncertainties of subsequent letters, they become less informative and they are less necessary to sample.

There are several reasons why it is the first letter which should be sampled: (a) Being next to a blank space, which can be picked up readily even by the low-acuity vision of the periphery, the fixation point can be programmed to center on or near the initial letter more readily than on any other letter than the last — and the last letter is too subject to grammatical constraints to be that useful. (b) Being next to a blank space, the shape of a letter at the beginning of a word carries a more characteristic and invariant pattern than that which occurs in the middle of a word. (c) Both with practiced and with unpracticed readers, the first few letters at the beginning of any word should be the most informative in the sense that they will offer the cue to a set of words in auditory storage: with unpracticed readers, who store letter by letter in auditory form and then sound them out, the sounding clearly depends on the first letter in a crucial fashion; the practiced reader, I assume, will not normally have to retrace his steps, to any extent, and if we also assume an automatic read-out from visual information storage to auditory storage, (cf. Glanzer and Clark; Levin; Sperling) probably in terms of involuntary fractional subverbalizations as the means of bridging long saccads between visual sampling, again the initial letters should be preferred.

In fact, there is evidence (Marchbanks and Levin) that readers do pay more attention to the initial letters in words, as determined by their errors of confusion in reading single words. If all of what I have been tracing out above is true to any degree, we should also expect them to be shifting their fixation so as to center successively the letters immediately following any blank space. This is a task which peripheral search guidance should well be able to accomplish. There is another, closely related one which it would seem likely that PSG could subserve: words differ greatly in length, and the smaller ones are usually functors: on, in, to, up, etc. In many cases they are probably redundant since their meaning is clearly given by context, once you know that some one of them occupies some particular place in a sentence; in other cases, the functor may be critical. In either case, it should be possible for the eye to detect that a word which is probably a functor lies at some distance out along the line of text in the periphery, and either so guide the fovea as to move to center it or, if it is probably redundant, to move to the word likely to be important which lies near it. I have tried to determine the average information value of each common functor over a variety of common sentences by determining reading time with the functors present and clearly legible, with the functors present but partially obscured, and with XXs substituting for functors which had been deleted. In the last two cases, a list of functors was printed at the head of the page to help the reader fill in their places (where such assistance was necessary); I have only used this technique with a few readers of widely disparate reading ability, but it does seem to be workable and, if it functions as it should, it might make it possible to test the assumption that word-length operates as a fixation-cue in accordance with the average uncertainty of that word-length.

Although it seems plausible to me that PSG should be able to mediate CSG in reading-sampling, as suggested above, the wherewithal must first exist: a child who is not able to guess, better than chance, what a word may be on the basis of having determined its first letter or two will have to spell out more (or all) of the word, in order to achieve correct reading, even if he does try occasionally to sample only the word-beginnings. If the functors do offer peripheral information via their characteristic word lengths, fixation deployment can only capitalize on that information to the extent that the reader has acquired the habits of expectancies conforming to those contingencies. And so, if all of the preceding is close to the truth, we should be able to test the stage of development of the component skills of a given reader by noting the effects of interference with each kind of redundancy-sampling. In the next section, I shall sketch very briefly a few illustrative (and promising) attempts at this indirect form of measure of the search patterns.

2. The effects of interference with PSG at different reading ability levels.

Two very different classes of interference were undertaken.

In the first, a low-friction transparent plastic slide was so arranged that the subject could scan a line of text by moving a clear spot, approximately 4 degrees wide, along the line, by placing his index finger in a shallow depression immediately below the clear region. In one condition, the general outlines of the type could be made out very indistinctly outside of the clear region (the effort here was to simulate the distribution of acuity around the fovea, and to externalize the subjects' search procedures); in the second condition, there was no visibility at all outside of the clear regions. Although only a few subjects have been run so far, the results appear to be those we would expect from the preceding analysis of PSG and CSG:

In moderately good readers, there is a massive drop in reading speed when the diffuse peripheral information is removed; with poor, beginning readers, the differential is slight or nonexistent. The number of subjects in each category is too small to evaluate statistically, and no further subjects will be tested until the conversion of the testing device to a basis of automatic recording has been completed. However, the following kind of experiments yielded the same results.

In the second class of experiments, the procedure employed was to use free devices of typography and format. In the procedure with which the most subjects were used, short stories (roughly graded as to reading difficulty) were prepared in two typographical versions. (Hochberg, Levin and Frail) In the "unfilled" (U) version, normal spaces were left between words; in the "filled" version, (F), the space between all words were filled with meaningless symbols made by superimposing an "x" on a "c" (at half pressure, so that the resultant darkness of the two characters together was roughly that of the surrounding letters): the peripheral view of the text thus comprised an unbroken line of type. Which story appeared in which version was balanced between two otherwise equivalent groups of subjects, and the material was presented for silent reading (followed by comprehension tests) at two age levels of subjects, i.e., twenty-four Ss from 1st and 2nd grades, and twenty-four from 5th and 6th grades. The dependent variable was reading time per character, and there was a highly significant overall drop in reading speed from the U to the F condition. Of primary interest in terms of using such indirect means to determine differences in reading behavior, however, is the following analysis:

Subjects were arranged in order of their reading abilities, as determined by their reading speeds on the normal, unfilled stories. There was a sharp difference in base-rate reading speed between the lowest third of the younger group and the remainder of the 48 Ss. Accordingly, the eight slowest first and second graders were selected for comparison with the eight fastest first and second graders with respect to the following measure: the difference in reading time, (F) minus (U), divided by the base rate, (U). According to prediction, the poorer readers should and did show less of a drop in reading rate induced by the F condition (because their knowledge of orthographic contingencies does not permit them to take advantage of a sampling procedure even when PSG is possible -- (in fact, there was even some improvement in some cases, perhaps due to the elimination of guessing tendencies, based on a budding form of PSG, which were still more often wrong than right). On the other hand the readers who direct their search to sampled places under the guidance of peripheral cues show much more loss.

C. Summary

It is argued that the normal perception of objects (and of representational pictures) places demands on the perceptuomotor system which involve the integration of the views obtained during the course of eyemovements consisting of relatively large excursions, movements which follow not a systematic scanning raster but which are contingent on the particular display being perused and, consequently, which must be guided by both peripheral vision and by cognitive factors. Reading demands small sequential systematic movements however, (at least in the early stages of the abilities' development) which I assume to be both difficult and unfamiliar to the beginning reader. For the practiced reader, his knowledge of the orthographic and syntactic consistencies within language, and his knowledge about the world, bring expectations or hypotheses, of various levels of span, which make it possible for him to revert to more natural large excursions in a scanning procedure. Some preliminary experimental data, suggesting such a sampling procedure by interfering with the performance of better readers and leaving poorer readers relatively unaffected, were discussed.

In two later papers, I intend to describe the results of experiments to test the ways in which the expectations produced by pictorial illustration improve the efficiency of the sampling- according-to-expectation procedure in reading text, and to discuss the results of experiments on expectation-confirmation as a major reinforcement in the acquisition, initiation and maintainance of reading behaviors.

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WHAT IS PROJECT LITERACY?

Project Literacy was organized at Cornell University on February 1, 1964, by a developmental projects award from the Cooperative Research Branch of the United States Office of Education. This project represents one of the major commitments of the Office of Education to basic research and curriculum development concerning both child and adult literacy.

The purpose of Project Literacy is to organize, in various universities, laboratories and state departments of education, research which is essential to understand the acquisition of reading skills. The major initial effort is to bring together researchers and educators from a variety of disciplines to plan research which, when taken as a whole, will give us more substantial results than any single study can provide. Each investigator in the research consortium will be completely responsible for his own activities. The project will provide mechanisms whereby the individual scientists can communicate their research strategies, problems and results to each other and when necessary they will be able to meet together. The research findings will be brought to bear on curriculum developments. When called upon, Project Literacy can provide technical research consultation. The group at Cornell University will also undertake a program of studies similar to those which will be initiated in other settings.

We believe that much current and potential research in learning psychology, visual perception, cognitive behavior, neurophysiology of vision, child development, descriptive linguistics, psycholinguistics, the sociology of educational innovation, research with culturally disadvantaged children and programmed instruction (to cite some examples) are essential to understanding literacy. Consequently, we are endeavoring to locate research interests which heretofore may not have been considered relevant to this crucial educational research area.