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THE RETRIEVAL OF LEARNING SETS BY THE EXTERNAL DISPLAY OF READING MATERIAL.

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THE VARIOUS PROCESSES AND CONTROLS INVOLVED IN THE VARIATION OF EYE MOVEMENTS ACCORDING TO READING MATERIAL ARE DISCUSSED. RELEVANT RESEARCH LITERATURE IS CITED, AND AREAS REQUIRING ADDITIONAL RESEARCH ARE OUTLINED. LANGUAGE TEXT CONTROL AND THE CENTRAL NERVOUS SYSTEM AS POSSIBLE LOCI OF CONTROL FOR EYE MOVEMENTS ARE EXPLORED. EVIDENCE SUPPORTING THE CONTROL OF EYE MOVEMENTS BY SEMANTIC REQUIREMENTS IS PRESENTED. IT IS CONCLUDED THAT LANGUAGE HAS SEQUENTIAL CONSTRAINTS INVOLVING LETTERS, WORDS, AND SEMANTIC CONTENT WHICH ENABLE A READER TO BE AWARE OF CERTAIN WORDS OR PHRASES WITHOUT ACTUALLY FOCUSING ON THEM. THE EFFECTS OF LOCATION OF A PARTICULAR WORD OR PHRASE IN A SENTENCE ON THE ABILITY OF A SOPHISTICATED READER TO DETERMINE THE WORD OR PHRASE ARE EXAMINED. THE PROCESSING OF LANGUAGE DATA IN RELATION TO SEQUENTIAL ORDER AND THE POSSIBILITY OF USING TRANSFORMATIONAL VARIATIONS OF SENTENCE FORMS TO STANDARDIZE OR INDEX EXTERNAL DEPENDENCIES OF EYE MOVEMENTS ON INTERNAL PROCESSES ARE ALSO DISCUSSED. A BIBLIOGRAPHY IS INCLUDED. THIS PAPER IS A PREPRINT TO APPEAR IN THE 16TH YEARBOOK OF THE NATIONAL READING CONFERENCE, 1967. (LS)

The Retrieval of Learning Sets by the External Display of Reading Material

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One gets the impression that teachers of reading, more often than not, have thought of reading as a display of materials from which the reader extracts some quality called "meaning." Of course reading teachers, by the nature of their task, are well aware that there is another level of analysis of the materials relative to the letters and words of the language. This analysis is the discrimination of the particular sign from the set of other signs as distinct from the sign's function or its referent. Some teachers add another process when the reader has the intention to learn materials he is reading.

In general, eye-movement variations may be noted for each of these reading processes. When the reader is concentrating on perceiving letters and words there is a concentration of fixations at the particular locus of the letter or word. When the reader is retrieving parts of his previous learnings, fixations are regular and relatively short in time. There are few regressions. When the reader is learning there are vertical and horizontal excursions to locate materials further afield than that on the line being read. There are regressions and concentrations on content words. Difficulties

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arise, however, when one attempts to quantify these impressions. In the first place, confoundings appear. Then too, about 40% of the words do not appear as directly focused upon. It is impossible to tell at any particular fixation the area of acuity which will allow recognition. Fixations appear between words. To complete the confusion the reliability of the placement of the central focus which is the reference point for measurement, is seldom available. Obviously, to date, eye-movement photography has raised many more questions than it has answered. (4, 5, 6, 8, 9, 12, 14, 24)

If we consider the gross characteristics of eye-movement photographs, however, even the more reliable type which do not attempt to locate eye fixations relative to a specific part of a text, (24) it is apparent that there are variations in the number and length of fixations when a particular individual reads. While in itself, this is not an astounding observation, the fact of variation raises a crucial question for the understanding of the reading process, namely, where is the locus of the control of the movements? If the movements are not all the same size (as they are not) i.e. if they do not cover the same number of significant units each time, some control must operate to determine what units to cover, when to regress, when inaccuracy of fixation has occurred, etc. It is apparent, from the rate with which these decisions have to be made that conscious control of these parameters is impossible at typical reading speeds. (15, 16)

There have been attempts to locate the control of eye-movements in the language display itself. The idea of "training" eye-movement is closely connected with the assumption that reading is controlled by information already present in appropriate units on the printed page. One might say then, language is read word by word and mean by this, that each printer's space marks out a separate language unit which must be processed directly from the display. Eye-movement photographs do not indicate fixations at every word, in fact, as we noted before, some 40% of the words are skipped. This apparent skipping might be an artifact, however, of the inability to determine how far from focus, peripheral acuity is extending. The number of words skipped by central focus increases continuously and (using percent of total words as the measure) linearly, from 5% of six-letter words skipped, to 75% of two-letter words skipped in some 300-lines of eye-movement photographs we examined. Nevertheless if the length of the acuity sufficient for perception were controlling one could count letter-space intervals between fixations and obtain a "near-constant." If one objects that this constant does not appear because parts of words are not meaningful units to process, and thus only a particular part of the "sufficient" acuity span is processed, this explanation itself assigns control to some locus other than the language text.

Taylor (24) asserts that to read "with complete accuracy" one must "see" all the words he reads. The difficulty here is with the word "see." There is the "seeing" of proof-reading where an accurate job requires ignoring the implications of words in order to note the accuracy of their construction. There is the "seeing" of reading a "who-done-it," where the intent to comprehend a puzzling situation is paramount. Here, the situations and their verbal elaborations are ordinarily well known to the reader; it is the particular arrangement that counts and the details of the input of that information are not even thought of. There is the "seeing" of reading Whitehead and Russell's Principia Mathematica where practically every sentence, for many of us, is so ladened with semantic information that a constant learning is required to keep up with the text.

Many psychologists would classify the above activities as complex processes with elaborate central nervous system controls. It is reasonable to argue, however, that all of reading cannot be a central nervous system operation. Lashley (15) observed that in a rapid sequential operation such as speech production, the discrete acts making up the production of long, rapid sequences have shorter latencies than the maximum transmission rate of fibers leading to and from the central nervous system. Licklider, Stevens and Haynes (16), Quastler and Wulff (22), and Pierce and Karlin

(21) have independently, and using different techniques, calculated the information transmission rate of oral reading as 35 to 45 bits per second--the fastest information processing rates which have been demonstrated for any human act. We assume that silent reading is an even more rapid process. Since it is unimaginable, within the framework of a naturalistic science, to have action rates greater than nerve impulse rates, the favored assumption is that peripheral coding allows the triggering of integrated sequences as units. Luria (17) speaks of these sorts of rapid motor acts as the elaboration of "melodies;" Osgood (20) speaking specifically of language calls them "predictive integrations."

The idea of the retina as supplying only afferent information has long supported the proposition that the retina is a passive passageway to the processing capacities of the central nervous system. Investigations by Gershuni, Leont'ev, and Sokolov (17) indicate that the retina incorporates effector elements which tune the peripheral receptors to essential components of the signal being received. One example of this phenomena is Granit's (11) demonstration that foveal flicker fusion points are raised by a steady light to the periphery and that peripheral sensitivity is enhanced by simultaneous macular stimulation. While these experiments are not concerned with patterns, there is at least the possibility that similar processes might enhance recognition or perhaps set-up a more favorable situation for recognition of high-frequency language patterns. It is interesting in this regard to note that in fixation records of first-graders, fixations on the word "the" (in our materials the only word occuring frequently enough to examine in this manner) dropped off with the number of occurrences of the word in the material.

The indications of peripheral control of visual processes do not offer complete explanation of all phenomena by any means. In Tinker's (25) study of eye-movements in reading formulas, the fixations for the prose-part of the context was very similar in pattern to regular prose text. At the formulas themselves, both algebraic formulas and chemical formulas, there was an immediate decrease of eye-movement span and an increase in time of fixation. This seems to be a fairly clear indication that difficult or unfamiliar materials require the exertion of central nervous system control. This control is not directly connected with the external display of the materials in any regular way we could discover. In Frandsen's (9) study of eye-movements in reading objective examination questions, the same phenomenon of control by content is exhibited. Frandsen explains the photographs where fixations are clustered around a particular response e.g. in a multiple-choice question with few or no fixations at the other choices, as an item where the subject knew the right answer. When the subjects get unfamiliar items there is an, almost, letter by letter searching, of all the alternatives. Again these seem to be clear cases of the control of eye-movements by semantic requirements.

Goldman-Eisler (10) has shown that the length of pauses in conversational speech is related to the informational content of the language at that point. The technique was to construct cloze tests for long and short pauses and to demonstrate the words removed after short pauses were much more accurately replaced than words following long pauses. Pauses less than ¼ second were considered phrase or punctuation pauses and were excluded. In oral reading by an accomplished reader, only phrase and punctuation pauses appear. Eye photographs, of the silent reading of familiar material, imply a similar situation. That is, reading, in these cases, takes place as if there were no differential information intake for various segments of the reading. This appears analagous to the findings in tachistoscopic studies that as exposure time is increased, an exposure time is reached where all words (whatever their frequency of occurrence in the language) are equally recognizable. Studies of words spoken in noise which show that frequency of occurrence is related to accurate perception of words only when a masking noise is present also seem relevant. The reading of familiar materials is also a well-practiced, habitual action which seldom goes beyond the recognition stage of mental processing. It is only when a task is imposed that interrupts the routine, that large variations occur in eye-movements.

There are a number of investigations which strongly imply that reading is not the continuous-input sort of operation as it is normally pictured, but rather, involves a sampling of the environment. One set of these studies concentrate on apparent periodicies in visual tasks resembling reading (1). Stroud and his colleagues (23) view their data from rotary pursuit studies as indicating sampling by the eyes. Barlow (2) describes perception as occuring early in the total activity of processing information. This chain of operations may be summarized as (a) an input which is partially sampled and selectively perceived, (b) other intervening central nervous system processes such as retrieval, storage, and reorganization under new learning, and (c) a feedback to the periphery to guide the next input or to trigger a motor act. These processes are conceived of as sequential and thus perception occupies only approximately the first third of the cycle.

Such constructions as the one given above are important when we consider such questions as, how can one know the next word until he "sees" it. If one answers, there is no way to know, he has made an implicit processing model which assumes a continuous visual input without feedback. To assume that a visual system does not have feedback makes the explanation of the many observations of the operation of constraints exceedingly tedious. It has become common in the last few years to demonstrate that language has sequential constraints--constraints involving at different times letters, words, and semantic content. In this regard, it is interesting to consider what happens when one attempts to have a computer "read" information in a printed form. One obvious approach is to have a "template" set up in the computer. When a matching form is put into the machine that form is passed into further processing. There are many problems however. Print sizes and shapes vary. There are capital letters and small letters. Words have different numbers of letters. Letter by letter identification is slow in computers as it is in people, etc. Most programmers have abandoned the template as a model.

Another approach is to analyze letters and words in relationship to specific shape and context paradigms which discriminate one sign from another. Only certain parts of letters and words are now used for recognition purposes. The judgments used are probabilistic and context becomes extremely important. David and Selfridge (7) say, "even knowing diagram letter of syllable frequencies can improve decisions about letters or phonemes....". They also say that syntactical, grammatical and even semantic information would improve recognition. The interesting point for this paper is that eventually the computer will not have to "see" every word. Some words in highly constrained positions do not have to be "seen" at all. Many other words are identified from the first few letters. The middle of the word is especially low in information. The first few and the last few letters reduce most of the uncertainty. Bruner (3) has also shown this result using human subjects.

When the organism is "reading," the intent, usually, is to derive significance from the graphic signs. Perception of what is being read at any particular point certainly has a sensory component, but it is not at all clear how much of this component is necessary for the perception to occur. There are some locales within the sentence which are so highly constrained that the sign is determined, for the sophisticated reader, before it appears. This ordinarily true, however, only if bilateral context is available. For example the missing word in the sentence, "The boys _____ going," is much more constrained than the blank in the fragment, "The boys _____." There are instances however where the semantics of preceding context, highly constrain language elements, occurring in a particular site of the passage. For example, note the following passages.

> "The Pythagorean theorem was the end product of long years of practical experience with triangles. In its abstract elaboration by Pythagoras, this _____"

With a high proportion of successes, the element represented by this blank would be supplied by readers capable of understanding the passage,without viewing a physical representation of the word.

The probability seems high, however, that bilateral context is available to the reader. As the eyes fixate on a particular point of a reading passage, language elements to the right, as well as to the left, are within the viewing area of the reader. Several studies have shown that the major effects of constraint is from five words or less on each side of the constrained word. Evidence derived from photographs of the "reading" eye indicates that words a short distance away from a point of focus are blurred in vision and severe distortion is present when the eye is in motion. Nevertheless, fixations do occur at the rate of four or five a second. Even if only three or four words are "put in" at each fixation the number of words which seem to introduce most of the constraint would be available in the organism within the maximum limit of one second and in many cases in less time. This input rate would represent a reading rate of some 720-1200 words per minute. This rate so far exceeds normal reading operations that again the probability is brought to mind that not input, but rather, central processing operations impede reading speed.

Another empirical indication that following context is available for use by the organism is the eye-voice span. If the source of light a subject is reading by, is suddenly extinguished, the subject continues to verbalize for some time after the event--he goes on for an average of about five words. These words must have been "put in" and continue in the process of decoding. Processing, then, by this indicator is lagging behind input. Thus, bilateral context would be available. Also, one may observe the phenomenon of regression. Even in good readers there is some regression. As reading materials become more difficult there is more regression. Regression is a rerun of a past input--a kind of redundancy. There is a great likelihood that the input, before the regression, was processed in part. Regression provides a situation, which not only allows total redundancy, but also supplies, in effect, a longer bilateral context.

Several studies have indicated that bilateral context i.e. words on both sides of a target word, reduce more uncertainly about the target word than words preceding only or following only i.e. unilateral context. This appears to evidence that processing of language data is not entirely in the sequential ordering of the input. There seems to be a basic difference however in the reading process and the sign deletion techniques by which the constraint of context is often measured. An unknown word in reading occurs at a particular sentence locus where a graphic representation is present, and there is usually no uncertainty about the sign. All the letters of the sign are known for example and, for the sophisticated reader, even if the sign is unfamiliar, he probably can group the letters into syllables and give a reasonably accurate pronunciation. Parts of the sign may give cues to possible decoding--the reader may recognize the root for example. On the other hand, if the sign itself is missing, as in a cloze deletion of words, the many cues connected with the perception of a particular word are not present. The subject must search for the most probable sign, usually among a number of signs with somewhat similar probabilities. Reading in this situation is no longer a many-cued, direct, recognition process, but now a more or less uncertain search problem is involved. The reader <u>may not</u> need to reduce his uncertainty about short range constraint at all. The decoding need in this process may be that of relating particular language units e.g. a prepositional phrase; the subject, to the larger topic of the passage. If this be true central processing in reading may only be difficult when (a) much of the material read is unfamiliar to the subject i.e. it is not in storage (b) the material is of such a nature that early parts of the passage are necessary for understanding later parts i.e. the cognitive load on memory is excessive (c) the subject lacks "rules" of the grammar (in the "immediate constituents" sense) so that his relating of various smaller language units is inappropriate or inefficient. The"total" impression of these tasks is that successful reading at most particular points in a passage is controlled by the "extensional, field-like" recognition matrix (whatever that means) which has preceded and which immediately follows, that point.

While there is an amount of observable evidence from which to draw inferences that internal control is operating, the specific processes at a molar or molecular level are much more obscure. What is needed is some sort of known variation of internal processes which may be used to index the external dependencies of eye-movements on this internal process. We consider one possible candidate for this standardization of covert processes to be transformational variations of kernals. It has been shown by Miller (19), Jenkins (13) and others, that various transformations of sentence forms called kernals (usually, the declarative, active form of the sentence)into, for example, the passive or the passive-negative results in an increased in reaction times to the sentence. While there are disputations about the actual ordering of the relative reaction times of the various transformation, gross relationships are the same in most studies e.g. the passive-negative transformation is always slower than the negative transformation alone. It would seem to be a test of whether eye-movements are controlled by these structural characteristics of the language to present various transformations and predict eye-movements changes connected with the supposedly greater informational load of the transformations.

The consistencies in eye-movement data to the present have been mainly noted in data across subjects. Average number of fixations per word decrease with age; fixations occur in reading languages elaborated left-right, up-down; good readers (by some cognitive criteria) have fewer fixations, i.e. longer spans, than poor readers; all these are examples of the state of our knowledge concerning fixations.

There are few examples of what we need to know to understand what fixations are all about within the individual subject.

Actually, we should not expect eye-movements to tell us the whole story of what the person is taking in when he reads. For most reading situations, we feel, he is only taking in cues to "material" which is already present in the organism. Reading, typically, is a selecting of parts of what we already know. The novelty is in a different arrangement of events than one we have used before and the substitution of material we have always used in one context into a different context. In this aspect it is an easy, enjoyable activity for the accomplished. When material foreign to our learning history is read, the task becomes quite different. More of the information must be gathered from outside the storage of the nervous system. Eye-movements seem to reflect this increase in difficulty.

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