EXPERIMENTS IN READING

Unusual presentations of printed matter suggest that reading is not simply stringing symbols together. A better description is that it is generating hypotheses about the meaning of the pattern of symbols

by Paul A. Kolers

I invite the reader to see what he can make of the following lines: On his first day in topsy-turvy land he was thoroughly disoriented. His feet were above his head; he had to search for them when he wanted to see if he could walk without kicking things.

Probably after a moment of confusion you were able to read the lines fairly rapidly. The interesting question, which has a revealing answer, is: Why was it so easy? You do not normally see English sentences printed this way; indeed, you may never have seen such printing until now. A number of experiments I have conducted on reading suggest that you were able to read the abnormal sentences partly because in reading one's concern is not so much with letters and words as it is with meaning. The letters and words are symbols; it is meaning that you are after, and even if the familiar symbols are altered, you can ascertain the meaning quickly once your visual system has found the clue that reveals the pattern of the symbols—in this case, that the letters are backward.

Not much is known about the constituents of reading. The subject is difficult to attack because a skilled reader performs his task so rapidly and smoothly that an investigator has trouble ascertaining the details of what is happening. I approached the problem by creating artificial conditions that manipulated the timing and spatial orientation of text, the direction of reading and even the language. The results refuted the major assumption that most people make about how reading proceeds.

The essence of that assumption is that one moves one's eyes along a line of print and down a column of a page, seeing each letter and silently forming each word. With the aid of Martin Katzman, who was then a student at Harvard University, I examined this notion that reading is essentially a serial integration of letters by presenting six-letter words to skilled readers (Harvard undergraduates). We did not present the words in a normal way; instead we showed them one letter at a time by means of a motion-picture projector, so that each letter appeared in the same place on the screen. Our words were in four categories: six-letter words that could also be regarded as two three-letter words (*cotton* and *carrot,* for example); words wherein the first or last three letters also spelled a word (*potter* and *before*); words that could not be divided into three-letter English segments (*dollar* and *knight*), and two three-letter words (*for* and *can*). We varied the length of time that each letter appeared on the screen.

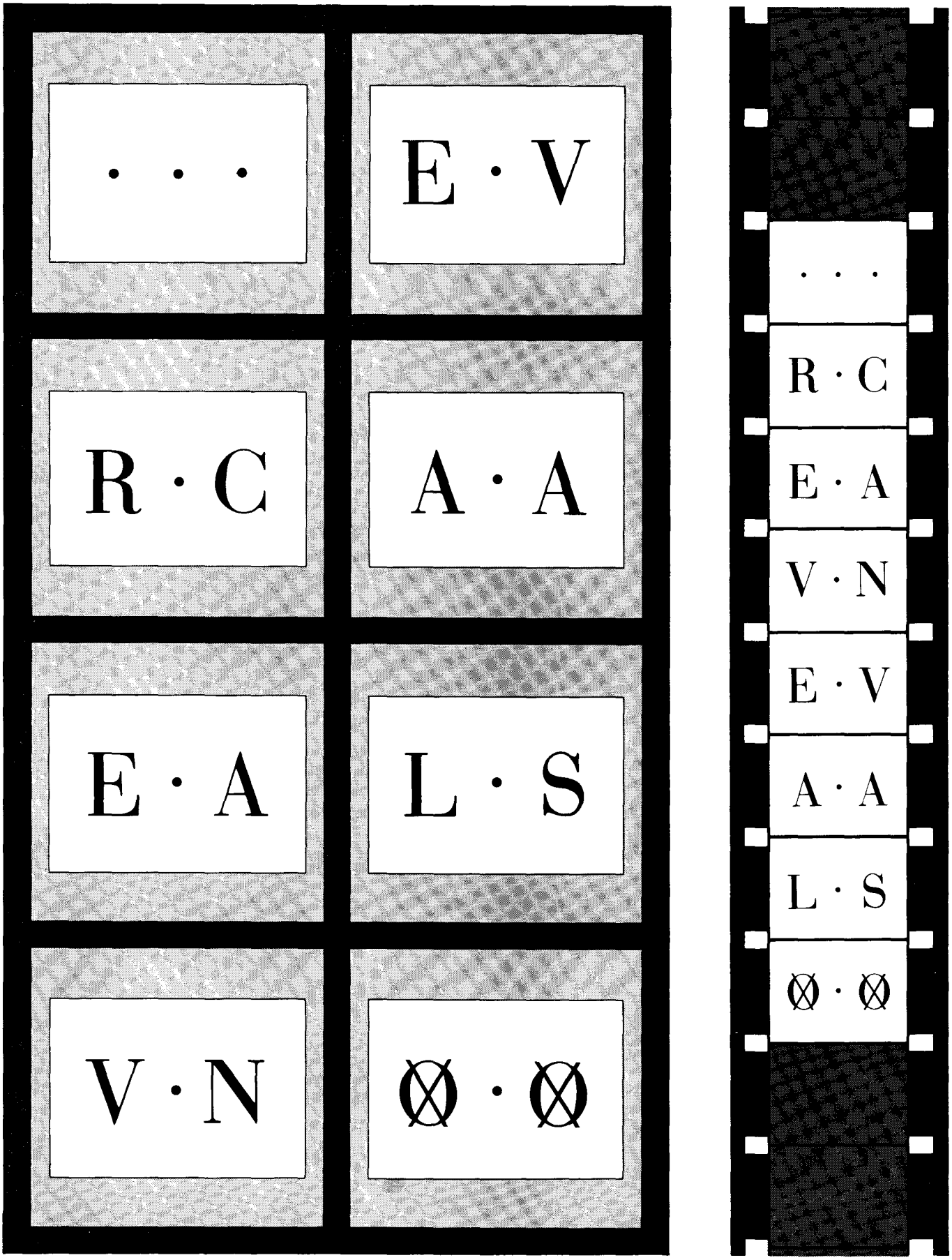
In some tests we asked the students to name the letters they saw; in other tests, to name the words spelled by the letters. Sometimes we told the students to begin naming the letters or words as soon as they could after a sequence began, and in other tests they were asked to wait until the sequence had ended before reporting their perceptions. Notwithstanding the different conditions of reporting, the results were remarkably consistent. On the average each letter had to be presented for between a quarter and a third of a second for the student to be able to name all the letters or the word.

English words have an average length of about six letters. If the best a skilled reader can do is to see three or four letters per second (the average rate in our experiment), and if he had to see every letter of a word in order to read it, he would be able to read about one word every 1.75 seconds on the average, or roughly 35 words per minute. At the time of the tests, however, Harvard freshmen were reading about nine times as fast—an average of some 300 words per minute. The experiment therefore disproved the idea that ordinary reading proceeds by a sequential perception of the individual letters composing words.

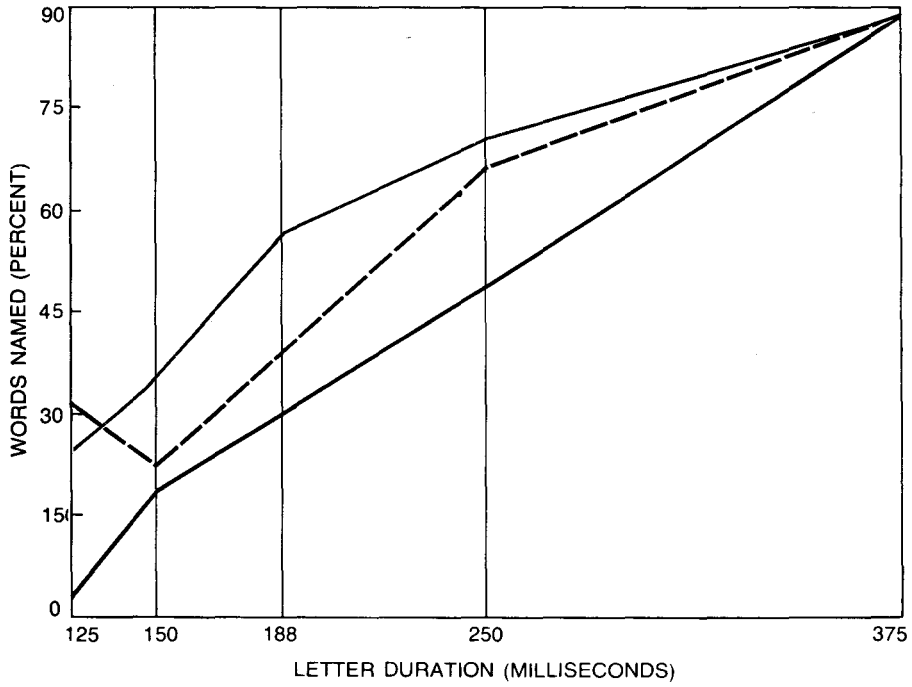
In addition to this finding the tests provided us with a useful observation. In many cases the students could tell us the letters that had been presented but hesitated, often for a rather long time, before naming the word spelled by the letters. In other cases they could name the word but misidentified the constituent letters. The significance of the observation is its implication that naming words is not necessarily a matter of perceiving their constituent letters. Perceiving a word in a sequence of letters involves something more: a meaningful bounding or grouping of letters.

This feat of bounding seemed to deserve more study, which I undertook with Clayton Lewis, then a student at the Massachusetts Institute of Technology, in an experiment involving M.I.T. undergraduates. We explored a number of conditions, two of which I shall describe. Again we employed a motion-picture projector to present letters in the same position on a screen. In one test the letters of two different six-letter words were presented simultaneously in pairs for brief intervals of time [*see illustration on opposite page*]. If the words were *canvas* and *dollar,* for example, *c* and *d* would appear in the first frame, *a* and *o* in the second frame and so on to the end of the words.

In one condition the students were asked to report only a single word. In another condition the test was to report both words. When only one word was required, the students scored correctly on 57 percent of the trials, but when the



PERCEPTION OF WORDS was tested by flashing two letters at a time on a motion-picture screen; together the letters formed two six-letter words such as the ones depicted at right. If the subjects were asked to name one word, they did so correctly on more than half of the trials, but success was rare when the subjects were asked to identify both words. The experiment therefore showed that the subjects, who were skilled readers, could not simultaneously process two different words when the perception was extended in time.



IDENTIFICATION OF WORDS or of individual letters in six-letter words varied according to the length of time that the letters were shown on the screen. One word grouping contained words that can be broken into two three-letter words (*color*). A second group (*broken line*) contained six-letter words that cannot be broken down, and a third group (*black*) consisted of six-letter sequences of three-letter words that do not combine into one word.

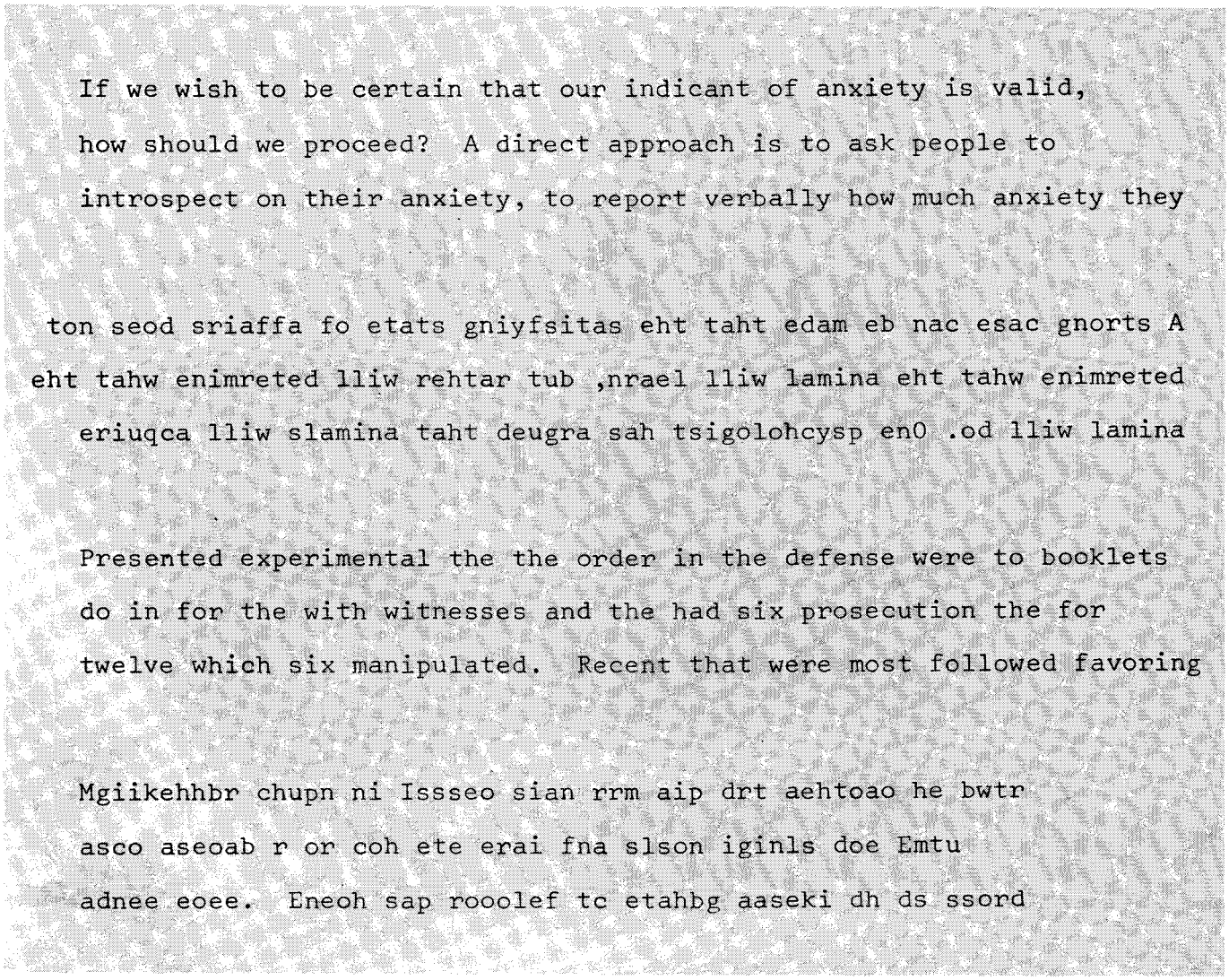
LETTER PYRAMID of nonwords refutes the notion that a reader can perceive an extended line of print in one glance. In fixing on the central *o* in successive lines one gets the subjective sense of seeing the entire line, but few readers can identify many of the adjacent letters, which indicates that a reader sees less detail than he may think he can see. The pyramidal figure was designed by the late Robert S. Woodworth of Columbia University.

request was for both words, the score was .2 percent (one correct report in 420 trials). Thus the finding was that these skilled readers could not simultaneously process two different words when the perception was extended in time.

In a variation we arranged pairs of letters so as to spell part of a single word, as in a test with a sequence of *c a, n v, a s, d o* and so on. Here the students reported both words correctly 7 percent of the time. A further breakdown is more significant: the first word was reported correctly 42 percent of the time, the first pair of letters of the second word 31 percent, the next pair 42 and the final pair 51. The finding therefore was that in establishing the perceptual identity of the first set of six letters the subjects actually lost in ability to report the letters immediately following, regaining that ability with time. Thus performance is not determined merely by the number and rate of presentation of letters; other factors, such as the set of letters (whether they form part of a single word or of two words that the reader is trying to perceive) and the activity of identifying the letters as a word, also influence the results.

A further implication of the experiment is that even the skilled reader has considerable difficulty forming a perception of more than one word at a time. Many students of reading believe that a reader does perceive several words at once, reading different parts of a line and particularly words near the one he is acquiring at a particular moment. Our experiments make it seem unlikely that such a strategy could be pursued profitably. One often has the subjective sense of perceiving more than the word one is looking at, but that sense may be somewhat misleading. The same subjective sense is present when one looks at rows of letters [*see bottom illustration at left*]. In reality one cannot name many of the letters in such a row, which indicates that a reader sees less detail than he may think he can see.

Reading material presented in the ways I have described bears little resemblance to the format normally encountered. Usually a reader sees a page of text and moves his eyes over it, ordinarily in a rightward and downward direction. In this way he perceives a sentence in a manner that preserves its main grammatical relations. A question that arises is how deeply ingrained the standard eye movements are. Would a reader employ them even when he might do better with a different strategy?



TRANSFORMATIONS OF TEXT were employed in experiments on the importance of direction of reading. The text at top is normal, the second one is reversed and the third one contains normal English sentences with a scrambled word order. The fourth text consists of pseudo-words. In the tests the subjects were able to read nonsense in a familiar direction more rapidly than sense in an unfamiliar direction, leading to the conclusion that the direction in which one is taught to read becomes a profoundly ingrained habit. Subjects read aloud; the experimenters accepted as "correct" pronunciation of pseudo-words anything close to English phonology.

Such questions motivated the next experiment, which showed to our considerable surprise that the eye movements one learns for reading become deeply rooted. The subjects for the experiment were again college undergraduates. The text they read was English prose transformed in various ways: reversed, scrambled and made into pseudo-words [*see illustration above*]. We asked the subjects to read aloud entire pages of these transformations both rightward and leftward. In reading from right to left the subjects therefore read normal English in the reversed typography and a kind of mirror image of normal English if they were reading a passage printed in the customary way. In reading from left to right the opposite relations held. Here, therefore, we could compare performance in reading English and non-English in familiar and unfamiliar directions. Another comparison was provided by the scrambled text: we could study the effect of direction of reading on words treated as units. The pseudo-words revealed the effect of direction of scanning when the text had only a minimal relation to English—the relation being that the letters were letters of the English alphabet and the lengths of the "words" were those found in English prose. (The source text for these experiments and many others I have done is George A. Miller's *Psychology: The Science of Mental Life*, which I chose for its polished writing and the intrinsic interest of its subject matter. I am grateful for his kind, if resigned, acceptance of the mutilations I have inflicted on his prose.)

The results of the experiment were as follows. Normal text was of course read far more rapidly in the rightward direction than in the leftward. The reversed text, however, was also read more rapidly to the right than to the left, notwithstanding the fact that the text was meaningful when read leftward but not when read rightward. The greater speed in reading the text rightward means that the direction of reading is a more important variable than the meaning or the sense of the message.

The effects of direction are further emphasized in the remaining examples. When scrambled text is read in either direction, it lacks normal syntactic relations, so that the reader might be thought to be identifying only single words, one at a time. Nonetheless, he still proceeds more rapidly in the rightward direction. Finally, in the pages of

pseudo-words, which bore only the minimal relation to English, the greater speed was also in the rightward direction. (In "reading" pseudo-words the students made sounds that corresponded more or less successfully to their knowledge of the letter-sound relations of English. We took as correct anything that approximated English phonology.)

In sum, our finding was that the effect of learning to read in a particular direction leaves an indelible impress on a reader's visual scanning habits. The impress is so strong that it leads him to read nonsense in a familiar direction more rapidly than sense in an unfamiliar direction. Even when he is reading one word at a time, he proceeds more rapidly in the familiar direction.

The evidence now in hand from other types of experiment on vision indicates that in scanning something that is not text the rigid pattern of moving the eyes from left to right does not appear. Apparently reading in a particular direction (which in certain languages of course can be vertical or from right to left) becomes a habit that is brought to bear on reading matter but does not necessarily affect the way one goes about acquiring other kinds of visual information [see "Eye Movements and Visual Perception," by David Noton and Lawrence Stark; SCIENTIFIC AMERICAN, June, 1971].

The methods I have described so far provide information about some of the constituents of reading, but they have usually involved texts that violated normal grammatical relations. In an effort to retain the grammatical features of text while slowing the reader down somewhat so as to make what he is doing more visible I tried geometric transformations of normal text [*see illustration on opposite page*]. Among them were texts in which each line was rotated 180 degrees in the plane of the page or 180 degrees on a horizontal axis or 180 degrees on a vertical axis. In addition I made similar transformations with one modification: every letter was rotated 180 degrees on an axis passing vertically through the letter, as in the two strange-looking sentences in the first paragraph of this article.

Such texts preserve all the linguistic features of normal connected discourse but create problems for the reader, who is faced with somewhat unfamiliar patterns. The problems act as a kind of magnifying glass to give the investigator a better look at what the reader is doing. In addition, of course, the problems introduce certain complications of their own. A study of these complications has proved rewarding as an approach to the topic of pattern recognition, since the transformations of text have certain well-defined relations to patterns that a person has seen before (normal text) but require him to employ subtle and skilled recognitive operations if he is to make sense of the transformations. I shall leave aside the complications and discuss only what the transformed texts suggest about how people read.

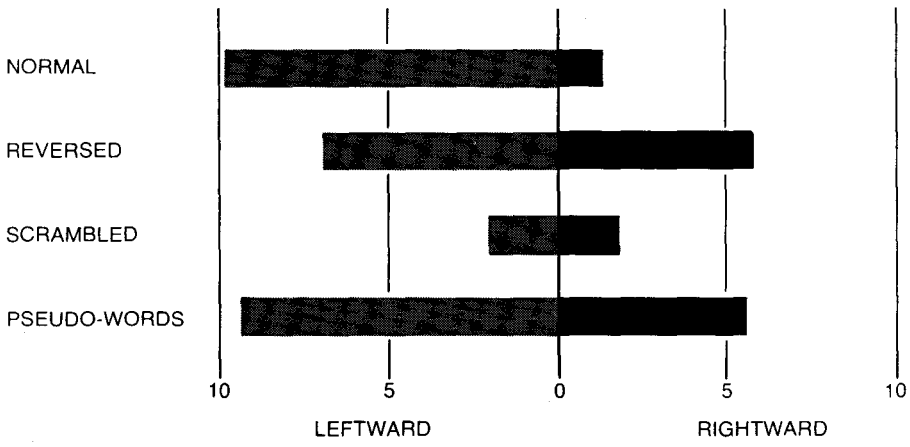
In one experiment with these texts undergraduates at Harvard and M.I.T. read one page in each of the transformations on each of eight successive days, reading aloud as rapidly and accurately as they could. We shifted the order of presentation in various ways so that no special effect of learning or practice would bias the results. Surprisingly enough, in the light of the difficulties the texts presented, the students developed considerable skill at reading the transformations, although of course the rate of speed was always lower than with normal text. More significant than their speed, however, was the pattern of their errors.

About 82 percent of the errors were substitutions of a recognizable English word for what was actually printed. Analysis of these substitutions has proved to be quite useful in illuminating the performance by the students. In one analysis we merely counted the number of letters in the words the students misread and the number of letters in the words substituted. We found that in misreading a word the students usually substituted for it a word of approximately the same length.

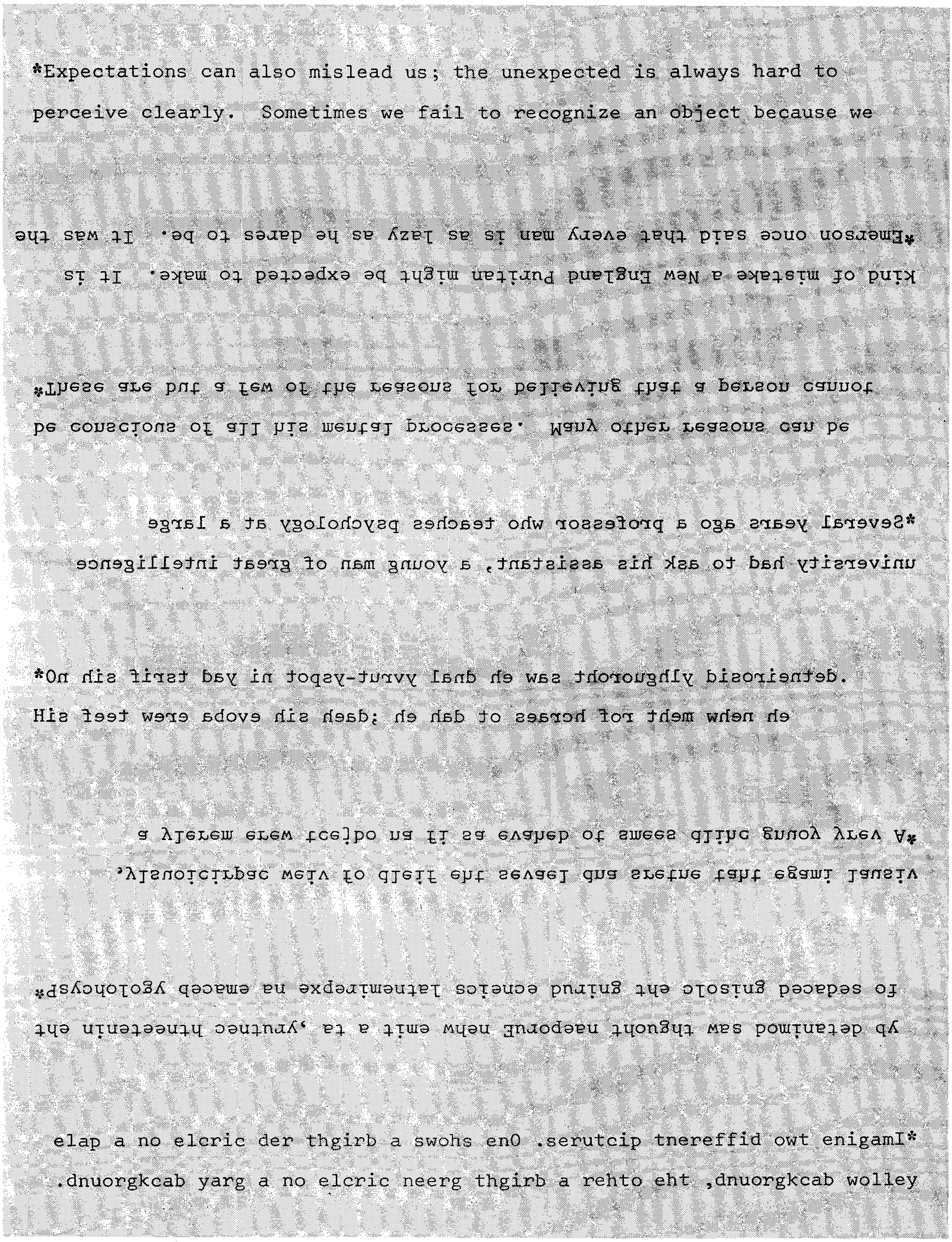
What makes this a surprising finding is that it is altogether implausible that the readers first decided which word to misread, then counted the letters in it, then found another word they knew with the same number of letters and then said that word as a substitute. People rarely count letters in the words they are reading. What seems to be the case is that the length of a word is a powerful clue that readers employ unconsciously in guiding their perceptual responses. Our readers matched, out of the stock of words they carried in their active vocabulary, a word with surface features of a length that matched the features of the word they were reading, but they did it without conscious deliberation and without seeing the word they substituted. Moreover, they did it so rapidly and normally that often the substituted word was left uncorrected and the reader continued his progress through the page.

Even more revealing is the nature of the grammatical substitution that was made. We examined the substitutions according to grammatical class (noun, pronoun, verb and so on), comparing the part of speech of the substituted word and the misread word. We found a high degree of correspondence. When the students misread a noun, they tended to substitute a noun; a misread verb was supplanted by a verb, and so on. Moreover, certain substitutions were never made, such as a noun for a conjunction and a pronoun for a noun [*see illustration on page 90*].

If it is implausible that the readers counted the number of letters in the words they misread, it is even more implausible that they consciously assessed



READING TIME was shorter for all types of reading done in a rightward direction than for reading done in a leftward direction. The bars show the average number of minutes required for the subjects to read a page of each type of text shown in illustration on preceding page.



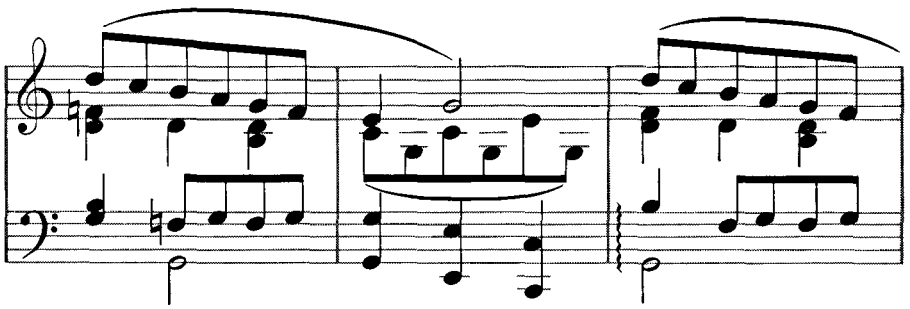
GEOMETRIC TRANSFORMATIONS of normal text were made by the author in an effort to retain the standard grammatical features of English while slowing readers down. The first four passages are respectively normal, reversed by rotating each line 180 degrees in the plane of the page, inverted by rotating each line 180 degrees on a horizontal axis and mirror-reflected by rotating line by line 180 degrees on a vertical axis. The bottom four text transformations are similar to the top four except that each letter has been rotated on a vertical axis through the letter. The asterisks were provided to show the subjects where to begin reading a transformed passage.

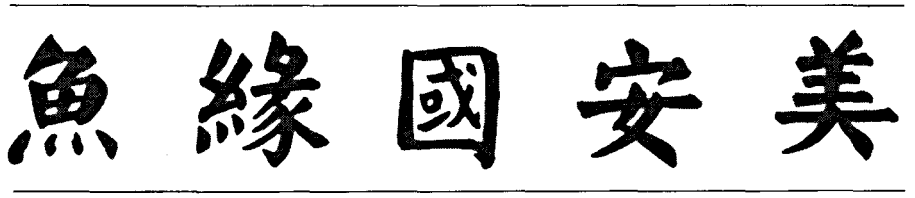
in much the way a normal reader does.

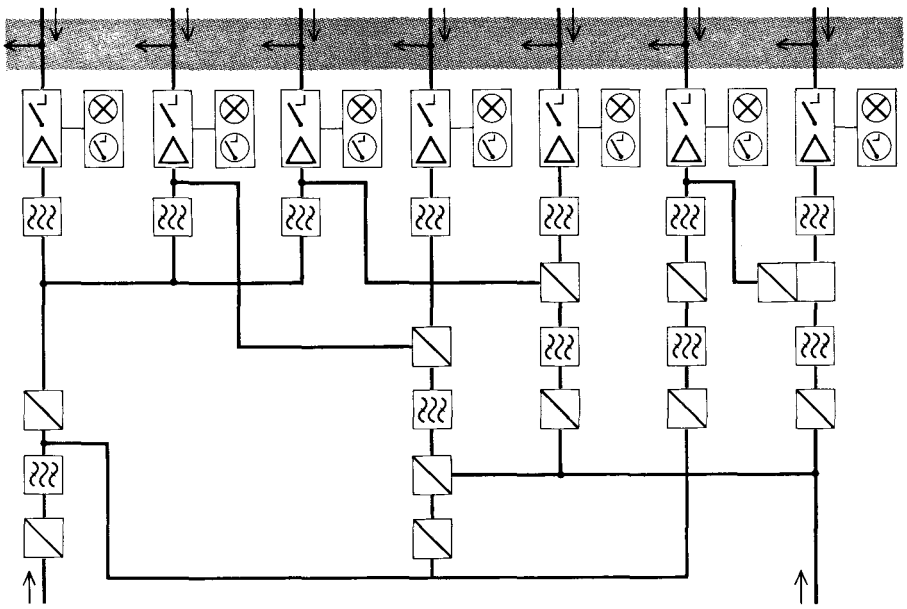
Another instance of internal language-generating is revealed by experiments with bilingual readers. The spontaneous and automatic nature of the process was evident in tests where bilingual subjects were asked to read aloud sentences made up partly of French words and partly of English words. (I described other results with these tests in an article on bilingualism in this magazine in March, 1968.)

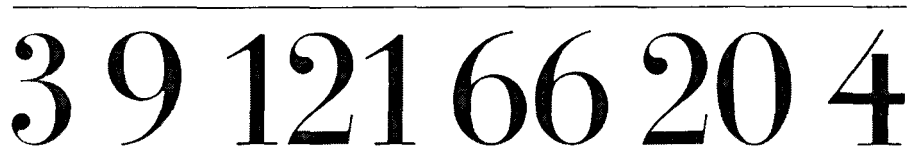
A typical sentence presented to a bilingual subject was: "His horse, followed by deux bassets, faisait la terre résonner under its even tread." The finding of interest was that often when the participants misread a word, they substituted for it the equivalent word in the other language. If the printed word was *porte,* the reader sometimes said *door;* if it was *of his,* he said *de sa,* and so on. Moreover, the readers often left these misreadings uncorrected, because they were paying more attention to the internal message they were generating than to the surface features of the text. For a person who knows both English and French it is usually irrelevant whether *door* or *porte* is what he hears or says; either word preserves the coherence of the message he is generating.

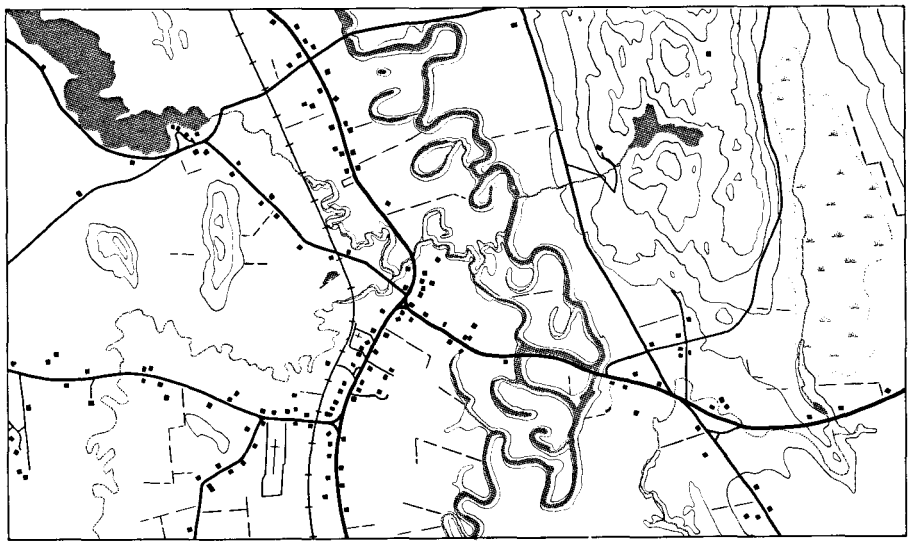
It is just this process of generating coherent messages from patterns of marks on a page that the skilled reader is engaged in. He is not, as one might think, involved in a piecemeal perception of individual letters and words. The process whereby the clues are selected and the messages are fashioned is one of the more challenging questions in the investigation of the way people process information. The challenge was put well by E. B. Huey, an outstanding early investigator of reading, when he said that "to completely analyze what we do when we read would almost be the acme of a psychologist's achievements, for it would be to describe very many of the most intricate workings of the human mind, as well as to unravel the tangled story of the most remarkable specific performance that civilization has learned in all its history."











DEFINITION OF READING is often extended to include matter presented in symbols other than an alphabet, including (*top to bottom*) music, logographic characters such as Chinese, a diagram of communication equipment, numerals and a map. Some of the techniques a reader brings to bear in reading a standard text presented in a familiar alphabet are also used for such symbols.