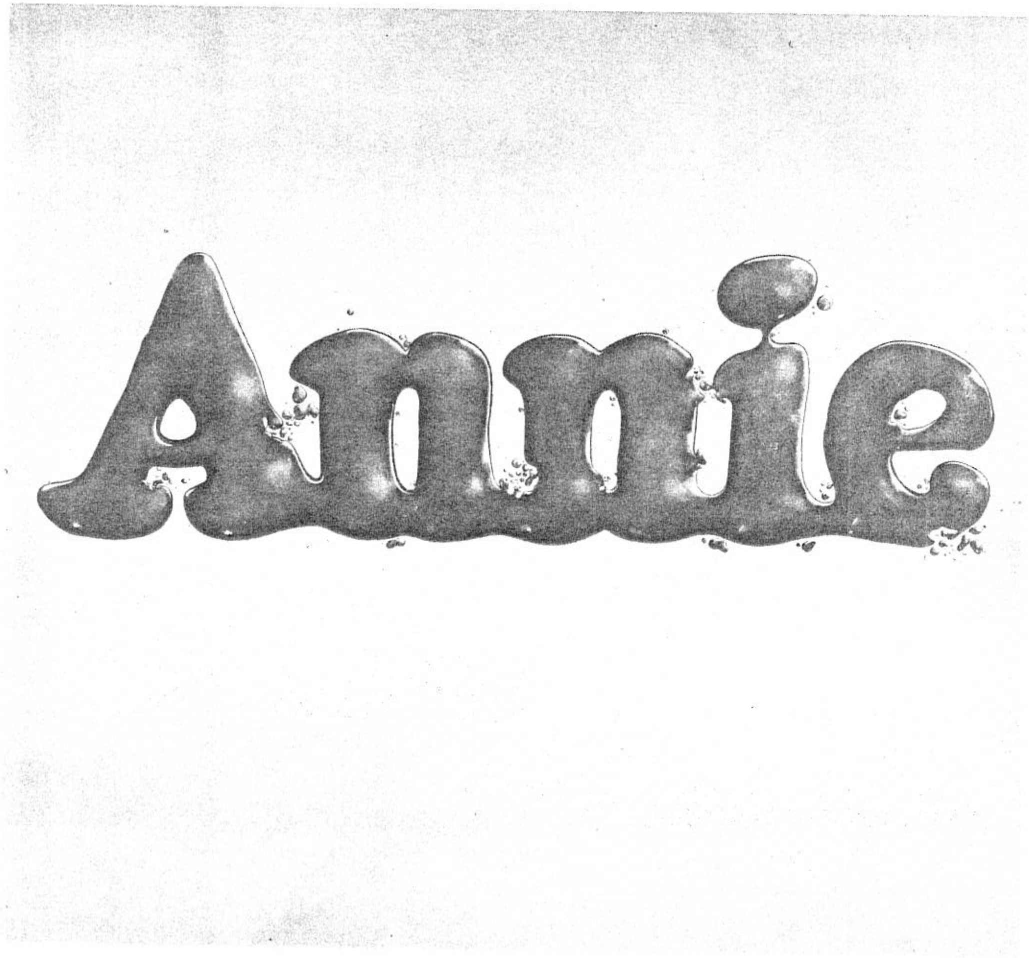
VISIBLE LANGUAGE

The Journal for Research on the Visual Media of Language Expression

Volume VI, Number 4, Autumn 1972



VISIBLE LANGUAGE

Conception & Formation →

Generation of symbols

- Relation to language generation
- Origin & evolution of the alphabet
- Post-typographic electronic generation
- Alphabetic prototypes
- Script and type design—hand or machine
- Influence of tools
- Augmented alphabets (e.g., ita); shorthands; "universal" scripts

- Electronic representation of speech
- Graphology

Application & Organization

- Language medium and language structure
- Comparative writing systems (e.g., phonetic/non-phonetic)
- Writing/speech relationships; phonetism of the alphabet
- Typographic & electronic letterform display
- Environmental "signing"
- Paleography
- Descriptive bibliography
- Practice of the arts: calligraphy, concrete poetry, letterforms in plastic media (e.g., Paul Klee)
- Comparative sight/sound media (e.g., musical notation)

VISIBLE LANGUAGE FORMS ON A SURFACE

← *Reception & Interpretation*

Physical Response

- Neurophysiological (e.g., vocalism in reading)
- Reading/hearing relationships
- Alphabetic efficiency; eye movements; fatigue; search
- Legibility & perception
- Initial visual discrimination training

- Machine reading

Mental Response

- Meaning/form dichotomy
- *Meaning*—language organization and comprehension
- *Form*—non-verbal communication of letterforms
- Visible/oral language dichotomy; "primacy of speech"?
- Visual encoding of verbal materials
- Conscious & unconscious
- Literacy

"Whenever social historians attempt to suggest the few most significant intellectual achievements of man, nearly always the one mentioned first is 'writing'—or some related reference to man's initial development of a visible language. This journal represents the first concerted effort to organize our investigation of every aspect of this visual medium of language expression."—from an editorial in the Winter 1971 number

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Visible Language, Volume VI, Number 4, Autumn 1972. Published quarterly (Winter, Spring, Summer, and Autumn) by *Visible Language,* c/o The Cleveland Museum of Art, Cleveland, Ohio, USA 44106.

Dr. Merald E. Wrolstad, *Editor and Publisher*
c/o The Cleveland Museum of Art, Cleveland, Ohio, USA 44106.

General information on *Visible Language*—addresses for correspondence, subscription rates, preparation of contributions, and advertising—will be found on pages 375–376.

One Second of Reading

Philip B. Gough

Two general topics are discussed: (1) the sequence of events that transpire in one second of reading, to suggest the nature of the processes that link them; and (2) the relation of this description to the acquisition of reading. Reading involves a rapid succession of intricate events—formation of a visual icon, letter-by-letter identification, and association with meaning through transposition into abstract phonemic representation—carried out with amazing rapidity and coordination in our complex information processing system. When first approaching reading, the child lacks the character recognition device (the scanner) and the device to convert the characters, once recognized, into systematic phonemic representations (the decoder). Specification of the mechanism by which letters are mapped onto entries in our mental lexicon is the fundamental problem of reading research.

Suppose the eye of a moderately skilled adult reader (henceforth, the Reader) were to fall on this sentence, and that he were to read it aloud. One second after his initial fixation, only the first word will have been uttered.[1] But during that second, a number of events will have transpired in the mind of the Reader, each the evident result of processes of amazing complexity. If we knew the train of events, we would know what the processes must accomplish and thus something of their

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[1] This estimate is based on my reading, as naturally as possible, 50 sentences drawn from *The Daily Texan* and presented tachistoscopically. The median interval between stimulus and response onset was just over 700 msec, and the average initial word required roughly 300 msec to produce.

This article is to be published as a contribution to *Language by Ear and by Eye: The Relationships between Speech and Reading*, edited by James F. Kavanagh and Ignatius G. Mattingly (the proceedings of a conference on The Relationship between Speech and Learning to Read in a series, Communicating by Language, sponsored by the National Institute of Child Health and Human Development, National Institutes of Health). Cambridge, Mass. & London, England: The MIT Press, 1972; pages 331–358

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Author's address: Psychology Department, University of Texas, Austin, Tex. 78712.

nature. If we knew this, we would know what the child must learn to become a Reader.

Accordingly, this paper is concerned with two topics. First, it tries to describe the sequence of events that transpire in one second of reading, in order to suggest the nature of the processes that link them. Second, it attempts to relate this description to some facts about the acquisition of reading. The description of the chain of events is intended to be exhaustive in the conviction that the complexity of the reading process cannot otherwise be fully appreciated. Thus it is detailed by choice, speculative by necessity, and almost certainly flawed. I hope these are virtues, for much of what is written about reading is either too vague to be tested or too banal to bother, and an analysis that can be attacked in detail can yield detailed knowledge. The consideration of research on reading in children, on the other hand, is anything but complete. Quite apart from the familiar methodological shortcomings which abound in this research, most of it is aimed at a level of description too gross to be of any use here. So rather than presenting an unavoidably dreary review of the literature. I have attempted to interpret the acquisition of reading in terms of the present model, and to fit selected experimental results into the resulting framework.

THE READING PROCESS

Reading begins with an eye fixation. The Reader's eyes focus on a point slightly indented from the beginning of the line, and they remain in that fixation for some 250 msec [Tinker 1958]. Then they will sweep 1–4 degrees of visual angle (say 10–12 letter spaces) to the right, in a saccadic movement consuming 10–23 msec, and a new fixation will begin. Barring regressions, and ignoring return sweeps (which take 40–54 msec), this sequence will be repeated as long as reading continues (up to at least six hours according to Carmichael and Dearborn [1947]). When the initial fixation is achieved, a visual pattern is reflected onto the retina. This sets in motion an intricate sequence of activity in the visual system, culminating in the formation of an icon.

Iconic Representation

The existence of the icon, a relatively direct representation of a visual stimulus that persists for a brief period after the stimulus vanishes, has been amply demonstrated [Sperling 1960, 1963]. I take the icon to be a central event, presumably corresponding to neural activity in the striate cortex [cf. Haber and Standing 1969]. I further assume that the icon is an "unidentified" or "precategorical" visual image, a set of bars, slits, edges, curves, angles, and breaks, perhaps corresponding to the output of simple cells like those identified by Hubel and Wiesel [1962].

Whatever the form of its contents, the iconic buffer has a substantial capacity. Sperling [1963] has shown that it can hold at least 17 of 18 letters presented in three rows of six. In the case of ordinary reading matter, it can be estimated that the useful content of the icon will include everything in an oval roughly two inches wide and an inch high, or about 20 letter-spaces of the line under fixation.[2]

The decay of the icon has been intensively studied [cf. Haber 1968, 1969]. It is known to persist for several seconds if the stimulus is followed by darkness, but for less than half a second if in light [Sperling 1963]. It can be erased or masked by a following patterned stimulus [Liss 1968; Spencer 1969].

The *formation* of the icon, on the other hand, has scarcely been studied at all. One reason is that it is excruciatingly difficult to investigate; the question of how long it takes to form an icon is no less than the question of how long it takes us to sense something. Simple threshold data are uninformative, for they only indicate how much (i.e., what duration of) visual energy is necessary to initiate the train of events which results in the icon. Masked threshold data tell no more, for they are naturally interpreted as indicating how long one icon exists before it is replaced by another. As far as I can see, the only relevant published data are to be found in studies of visually evoked potentials [e.g., Dustman and Beck 1965]. If a flash of light is presented to the eye, it is reflected in detectable changes in electrical potential at the occipital cortex no less than 50 msec later;[3] Dustman

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[2] I am indebted to Kent Gummerman for this estimate. It is based on "(a) acuity data for viewing in the horizontal meridian [Feinberg 1949], (b) Wertheim's [1894, p. 185] 'iso-acuity' ellipses that show areas of equal acuity in all directions, and (c) the conservative assumption that a letter can be resolved if the thickness of its component lines can be resolved by the eye" (Gummerman, personal communication).

[3] There is an early component of the wave at approximately 43 msec, but Dustman and Beck feel that it is not correlated with stimulus awareness.

and Beck [1965] have suggested that wave components with mean latencies of 57 and 75 msec are related to awareness of the light. Assuming that patterned visual information is processed no faster than a flash of light, we might infer (acknowledging the length of the leap) that the icon could not be formed in less than 50 msec, and that its full development may require closer to 100 msec.[4]

Given these assumptions, we are led to suppose that the Reader's initial fixation yields an icon containing materials corresponding to the first 15 to 20 letters and spaces of the sentence (e.g., "Suppose the eye of a"). This icon will become fully "legible" in something like 100 msec. It will last until it is replaced by the icon arising from the Reader's second fixation, some 250 msec later.

In the meantime, the lines, curves, and angles of the first icon will be recognized as familiar patterns. I assume they are identified as letters.

Letter Identification

Letter recognition is very rapid. There is striking evidence that even unrelated letters can be recovered from the icon at rates of 10–20 msec per letter.

One such datum was provided by Sperling [1963], who found that if a random matrix of letters was followed immediately by a patterned mask, the number of letters reported increased linearly with the duration of the matrix, one letter every 10 msec, up to a limit imposed by memory. Since premask stimulus duration is directly related to icon duration, this result presumably reflects the rate of readout of letters from the icon into a more durable register.

Given that simple recognition thresholds have been shown to be lower for words (and even pronounceable nonsense syllables; Gibson, Osser, et al. [1963]) than for random strings like Sperling's, it would be interesting to see if their letters can be read out even more rapidly. To my knowledge, the relevant experiment has not yet been conducted.[5] But there are data that suggest a comparable rate of letter identification with meaningful materials.

First, Scharf, Zamansky, et al. [1966] found the masked recognition threshold (using Sperling's own mask) for familiar five-letter words to be roughly 90 msec (under high luminance). This fact provides little comfort for any assumption that read-out of letters from the icon is more efficient for meaningful or pronounceable materials than for random strings of letters; Sperling's results show that under the same circumstances, four or five unrelated letters can easily be registered.

Second, Michael Stewart, Carlton James, and I [Stewart, James, et al. 1969) found that visual recognition latency—the time between presentation of a word and the beginning of its pronunciation—increases steadily with word length in letters, from 615 msec for three-letter words to 693 msec for ten-letter words. The function is negatively accelerated; the increase in latency with length is greater with short words than long. But the data are compatible with the assumption that letters of words are read out of the icon at a rate of 10–20 msec per letter.

Third, W. C. Stewart and I [Gough and Stewart 1970] have measured how long it takes readers to decide that a given string of letters is a word or not. One of the variables we manipulated was word length. We found that four-letter words are acknowledged some 35 msec faster than six-letter words, again consistent with the assumption that each additional letter requires an additional 10–20 msec for readout from the icon.

These data, among others, suggest that letters are recovered from the icon *as* letters, that the evident effects of higher levels of organization (like spelling patterns, pronounciability, and meaningfulness) on word recognition and speed of reading should be assigned to higher, and later, levels of processing. It is worth noting that if this analysis is correct, then it can be, at best, a half-truth to say that we do not read letter by letter.

Suppose that letters are identified and read out of the icon at a rate of 10 to 20 msec per letter, starting the moment the icon is formed. Since the icon should endure for some 250 msec, between one and two dozen letters could be identified from it even if readout were strictly serial. With a conservative estimate of three fixations per second, and assuming the average word to contain seven letters, even the lower

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[4] Presumably the latency of the icon will vary with the intensity of the stimulus (and perhaps with its complexity).

[5] Gilbert [1959] came close when he presented linguistic segments (words and phrases) of various lengths for various durations, and examined the amount recovered as a function of length of material and exposure duration. But his materials were presented by film, so that control over stimulus quality and duration was crude, and he presents only a rough general description of his materials.

value of letter transfer (i.e., 12 per fixation) would yield a reading speed in excess of 300 words per minute.

I see no reason, then, to reject the assumption that we do read letter by letter.[6] In fact, the weight of the evidence persuades me that we do so serially, from left to right [cf. White 1969]. Thus I will assume that the letters in the icon emerge serially, one every 10 or 20 msec into some form of character register.

How the letters get here and what form they take once they have arrived are intriguing questions. But more important is what is done with them. Clearly, letters are not the stuff of which sentences are made. They must be associated with meanings; they must be mapped onto entries in the mental lexicon. The specification of the mechanism by which this is accomplished is, as I see it, the fundamental problem of reading.

The Mapping Problem

There are two superficially appealing possibilities. First, one might assume that the lexicon is directly accessible from the character register, that the Reader goes "directly" from print to meaning. This possibility is appealing to some theorists [cf. Kolers 1970] at least in part because of the nonalphabetic (i.e., neither phonemic nor syllabic) character of many orthographies. Since readers of such orthographies have to learn thousands of arbitrary associations between printed and spoken words, they could as easily learn direct associations between the orthographic words and their meanings and circumvent the spoken word altogether. And if they can do it, so can we.

We can, indeed, but only at great (and quite unnecessary) expense. Every potential Reader has a lexicon that is accessible through phonological information; he can understand the spoken word. Presumably, then, each of his lexical entries contains a phonological representation, and he has a retrieval mechanism that can address the entry through that representation. If he learns to assign such a representation to the printed word, the mapping problem is solved, and he quickly becomes a Reader. If he does not, he must add an orthographic representation to each of the tens of thousands of lexical entries (to say nothing of constructing a completely new retrieval mechanism to make use of them). The Reader of a nonalphabetic orthography might do this, for his is Hobson's choice. But we have a significant alternative, for while the orthography of English is complex and its rules are numerous, no one has seriously proposed that the number of of these rules approaches within a factor of 100 the size of our lexicons. If there is any principle of cognitive economy, it surely must demand that we do not acquire tens of thousands of supererogatory associations, and we must not go straight from print to meaning.

The second possibility is, in this respect, appropriate: it is that we go from print to meaning by way of speech. On this view, the Reader applies orthographic rules to the contents of the character register, converting them to speech, and then listens to himself. All the Reader must add to his cognitive equipment are the orthographic rules. Nothing needs to be added to the lexicon; no new retrieval system needs to be constructed.

The advantages of this hypothesis are obvious. It is a venerable one, and it has prompted any number of studies of subvocal activity during reading (cf. Conrad's paper in this volume). But I find it untenable, for I do not believe that the device it proposes can work fast enough. Recall that M. Stewart, C. T. James, and I [1969] found that production latency for a three-letter word is in excess of 600 msec. A highly motivated and practiced subject can push this down to 500 msec. Subtracting the 32 msec our voice key consumes, the 10 msec or so it requires for a nervous impulse to travel from the mid-brain to the larynx [Ohala 1970], and another 5 or 10 for it to get to the mid-brain from the motor cortex, one is still left with well over 400 msec for an instruction to speak to be assembled. Even ignoring the additional time required for a circuit through some version (however abstract) of an auditory loop, a Reader would not understand a printed word for better than 400 msec after his eye fell on it.

Clearly, we do not know just how long it takes to understand a word. But what may be relevant evidence was obtained several years ago in a study by Rohrman and myself [Rohrman and Gough 1967]. We asked subjects to decide if pairs of words were synonymous or not, and measured the latencies of their decisions. On some trials, we announced that a pair would be presented in two seconds by saying "set"; on others, the warning signal was one member of the pair to be

[6] Elsewhere [Gough 1968] I have tried to argue that the traditional arguments against this notion are without foundation.

judged. We found that giving the subject one member in advance reduced his decision latency by roughly 160 msec. If it is assumed that simultaneous presentation of the pair requires a serial search for the two meanings, and that giving one word in advance eliminates only the retrieval of its meaning from the total decision process, then this result indicates that the meaning of a printed word is located in something on the order of 160 msec. (This result is, in light of the present model, fascinating: if the icon of the word was formed in 100 msec, then it suggests that the meaning of a word is located as fast as its letters can be read out of the icon.) This interpretation is clearly open to question, but if the estimate is anywhere near the true value, then the Reader understands a word well before he can begin to utter it, and the speech-loop hypothesis cannot possibly hold.

In light of these considerations, I am led to a third hypothesis, one that claims the advantages of both (and the disadvantages of neither) at the small price of a charge of abstraction. Suppose it is assumed that the Reader maps characters, not onto speech, but rather onto a string of systematic phonemes, in the sense of Chomsky and Halle [1968]. Systematic phonemes are abstract entities that are related to the sounds of the language—the phonetic segments—only by means of a complex system of phonological rules. Thus it is easy to imagine that formation of a string of systematic phonemes would necessarily take place at some temporal distance from (i.e., some time before) the posting of motor commands, and the prohibitive cost of passage through the speech loop would be eliminated. Moreover, since lexical entries must contain, in addition to their semantic and syntactic features, a lexical representation in systematic phonemes, it seems reasonable to assume that the speaker of a language employs, in the comprehension of speech, retrieval mechanisms that access the lexical entries through these lexical representations. If characters are converted into comparable representations, then available retrieval mechanisms could be engaged, and the search for meaning in reading would require no costly new apparatus.

Obviously, this hypothesis is highly speculative, and I can offer no experimental evidence in support of it.[7] But Halle [1969] and N. Chomsky [1970] argue persuasively for a similar view, and I know of nothing to preclude it. More important, it provides the basis for a coherent account of a central problem in the acquisition of reading, as I will attempt to show later.

Thus, I will assume that the contents of the character register are somehow transposed into abstract phonemic representations. If, as Chomsky and Halle argue, the orthography of English directly reflects this level of representation, little processing will be required; otherwise, more complex transformations (e.g., the grapheme-phoneme correspondence rules of Venezky [1970]) will yield a string of systematic phonemes that can then be used to search the mental lexicon.

Lexical Search

Whether the preceding hypothesis is correct remains to be seen. But whether by this mechanism or by some other, lexical entries are ultimately reached; the Reader understands the words of the sentence. Too little is known about word comprehension to suggest how it is accomplished or even to constrain speculation in any serious way. So I will adopt what I take to be the simplest assumption: that the words of the sentence are understood serially, from left to right.

Apparent objections to this hypothesis lie in the prevalence of lexical ambiguity. First, if words are understood one at a time, then it seems likely that they will frequently be misunderstood, at least until context demands and receives assignment of a new reading. Second, it would seem that prior context would determine the course of lexical search, a procedure not incorporated in the present model. The first is no real objection, for words often are misunderstood momentarily, and the presence of lexical ambiguity in a sentence demonstrably increases the difficulty of processing the sentence. For example, Foss [1970] has found that if subjects are asked to monitor a sentence for the presence of a given phoneme, their reaction time to the target is increased if it follows an ambiguous item. As to the second point, several experiments in our laboratories have failed to find evidence

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[7] Since this paper was delivered, Herbert Rubenstein has reported that subjects take longer to decide that a nonsense word which is homophonic with some English word is *not* a word than to make the same decision about nonsense items which are not homophonic with any English lexical item. This result is, in my view, persuasive evidence for the hypothesis that the printed word is mapped onto a phonemic representation by the Reader.

that the disruptive effect of ambiguity can be eliminated by prior context. Foss has found the same increase in phoneme monitor latency after an ambiguous word even when that word is preceded by a context that completely disambiguates it. In pilot studies, several of my students have found that it takes longer to decide if a pair of words are related when one is ambiguous than if it is not, even when the unambiguous word is presented first (e.g., *prison-cell* takes longer than *prison-jail.*) Thus we have (as yet) found no evidence that disambiguation takes place until *after* lexical search.

Such evidence suggests that the abstract phonemic representation is assigned the first lexical entry that can be found. This is consistent with the results of Rubenstein, Garfield, and Millikan [1970] and W. C. Stewart and myself [Gough and Stewart 1970], which show that words are acknowledged to be words more rapidly if they are ambiguous than if they are not (with form and frequency equated). This result suggests that the various readings of a polysemous word are stored separately in the mental dictionary, rather than under a single heading (as they are in Webster's). Interestingly, Rubenstein, Lewis, and Rubenstein [1971] have found that this result does not hold for systematically ambiguous items (i.e., items like *plow*, in which the ambiguity lies only in grammatical category); consistency demands the assumption that these constitute single entries with alternative syntactic features specified.

Thus, lexical search would appear to be a parallel process, with the race going to the swift. When the first entry is located, its contents are accepted as the reading of the word until it proves incompatible with subsequent data; in the case of a systematically ambiguous word, its grammatical category can remain unspecified until further information is provided. In either event, the contents of the lexical entry yielded by each successive word must be deposited somewhere to be organized into a sentence. Primary memory is a likely spot.

Primary Memory

A small-capacity buffer storage system where 4 to 5 verbal items are maintained for a matter of seconds is postulated in many current models of memory [cf. Norman 1970]. An item entering this primary memory (PM) [Waugh and Norman 1965] is generally thought to be subject to any of four fates. If it is ignored, it will simply (and rapidly) decay; on the other hand, it can be renewed through rehearsal. When the PM is full, an item in residence must be displaced if a new item is to enter. Finally, it may be transferred or copied into a more permanent store, the secondary memory.

There is one impediment to the assumption that the PM is the temporary repository for the content of a lexical entry. It is widely assumed that the contents of the PM are primarily acoustic or articulatory or phonemic [e.g., Baddeley 1966; Conrad 1964], largely because it is readily shown that verbal items are easily confused on this basis in short-term memory. I find this argument shaky.

First, confusion based on supraphonological properties of items in short-term memory can be demonstrated quite easily. Cornbleth, Powitzky, and I have found that lists of six nouns are more easily remembered if all are singular or plural than if singulars and plurals are mixed in a list; a variety of controls show that the effect cannot be attributed to confusion at the phonological level. The same appears to be true of verbs and tense, *mutatis mutandis*. If confusion data suggest that phonological information is in the PM, then reasoning from appropriate data leads to the same conclusion regarding syntactic or semantic properties. Second, Craik [1968] has shown that the immediate memory span is virtually identical for words of one to four syllables. This clearly suggests that the capacity of the PM is not defined by acoustic, articulatory, or even phonemic parameters, for all of these surely must vary from one-syllable to four-syllable words.

These data, I think, justify the assumption that the contents of lexical entries—including phonological, syntactic, and semantic information—are deposited in the PM, presumably one entry to a cell. The PM thus would become the working memory for the mechanisms of sentence comprehension.

There are many observations consistent with the assumption that the PM and the comprehension device interact in some such fashion. Three might be noted. First, it is obvious that far more words may be retained in sentences than out of them; sentences are remembered better than lists. In the present model this would be explained by assuming that when words are processed into sentences, the resulting structure is allocated to a further storage system with a much greater capacity. I am inclined to identify it with the secondary memory of the memory theorists, and to propose that items pass into secondary memory only when they are related to one another, or integrated in some fashion akin to comprehension. But that is another matter. For the present purpose, it suffices to assume that when a sentence is understood, it is deposited in the Place Where Sentences Go When They Are Understood (PWSGWTAU).

Second, when the contents of the PM are integrated, the PM can be cleared and new items entered. Support for this notion comes from a series of recent experiments by John Mastenbrook and myself (1971), in which we have found that if a subject is asked to recall a five-word sentence together with five unrelated words, his recall is significantly greater if the sentence is presented before the list than vice versa, independent of recall order. This is easily explained in the present model: if the list is registered first, PM is full when the sentence arrives, and it can be processed only at the cost of some items from the list, whereas if the sentence arrives first, it is quickly understood and the PM is cleared when the list arrives.

Third, the model predicts that any sentence whose initial words exceed the capacity of PM before they can be understood (i.e., before their grammatical relations can be discovered) will prove incomprehensible. This is just the case with sentences self-embedded to a degree of 2 or more.

The evidence, then, supports the assumption that the PM provides a buffer memory for the comprehension device. In my opinion, we have no good idea how that device works; the question is being studied and debated intensively [cf. Gough 1971]. For the present purpose, it suffices to assume that some wondrous mechanism (which we might dub *Merlin*) operating on the information in the PM, tries to discover the deep structure of the fragment, the grammatical relations among its parts. If Merlin succeeds, a semantic interpretation of the fragment is achieved and placed in the ultimate register, the PWSGWTAU. (If Merlin fails, we would assume that the fixation will be maintained to provide further processing time, or that a regressive eye movement would be called for. This is obviously consistent with the well-known facts about eye movements and difficulty of material [cf. Tinker 1958].)

Assuming success, the obtained deep structure provides the basis for the formation of a superficial structure containing the formatives from PM; application of phonological rules to this structure will yield instructions for the pronunciation of the fragment, and the Reader will begin to speak.

At this moment, some 700 msec have passed since the Reader's eye fell on the sentence. By this time, he is probably into his third fixation, perhaps 30 spaces into the sentence. The material from the first fixation is in the ultimate register (the PWSGWTAU); that from the second fixation is crowding into the PM.

I have tried to summarize the history of the 700 msec in Table 1, where the contents of each of the proposed stages of processing are specified at 100-msec intervals. Obviously, most of the entries are little more than plausible guesses. But the table suggests just how much must have happened. Some 20 to 25 letters have been internalized as characters, and converted into abstract phonemes. Perhaps a half dozen lexical entries have been located, and their contents copied into PM. The grammatical relations between some portion of these have been discovered, and the construction of a deep structure has begun. The semantically interpreted items have been inserted into a surface phrase-marker, and that, in turn, has been translated into motor commands.

On the outside, the Reader has rotated his eyes a few millimeters and he has begun to move his mouth. But on the inside, there has been a rapid succession of intricate events. Clearly, this succession could only be the product of a complex information processing system. That which has been proposed herein is outlined in Figure 1. It contains components that are asked to perform amazing feats with amazing rapidity, and precisely in concert. It remains to be seen whether this model bears any resemblance to reality. But it does suggest the complexity of the system that must be assembled in the mind of the child who learns to read.

Table 1
Level of Representation as a Function of Time

Msec	Material under Fixation	Level of Processing: Lines, Curves, Angles	Level of Processing: Letters	Level of Processing: Systematic Phonemes
000	Suppose the eye			
100	" " "	Suppose the eye	s	
200	" " "	" " "	. . . pose th . . .	sŭb = p
300	ose the eye of a mod	" " "	. . . e the e . . .	. . . = pōz#∂ . . .
400	" " "	ose the eye of a mod	. . . e eye o . . .	. . . z#∂ē#i . . .
500	of a moderately skil	" " "	. . . ye of a . . .	. . . i#uv#ǣ . . .
600	" " "	of a moderately skil	. . . e of a . . .	. . .v#ǣ#m . . .
700	" " "	" " "	. . . oderate . . .	. . . #mɔde . . .
800	tely skilled adult r	" " "	. . . erately . . .	. . . cræt# . . .
900	" " "	tely skilled adult re	. . . led adu . . .	. . . #ly#s . . .
1000	adult reader (hencef	" " "	. . . d adult . . .	. . . skIld . . .

Table 1 (Continued)

Msec	Level of Processing: Lexical Entries	Level of Processing: Semantic Representation	Level of Processing: Phonetic Representation	Vocalization
000				
100				
200				
300	$\begin{bmatrix} +V_t \\ +\text{ment} \\ \cdot \\ \cdot \\ \cdot \end{bmatrix}$			
400	$\begin{bmatrix} +V_t \\ +\text{ment} \\ \cdot \\ \cdot \\ \cdot \end{bmatrix} \begin{bmatrix} +\text{Art} \\ +\text{Def} \\ \cdot \\ \cdot \\ \cdot \end{bmatrix}$			
500	$\begin{bmatrix} +V_t \\ +\text{ment} \\ \cdot \\ \cdot \\ \cdot \end{bmatrix} \begin{bmatrix} +\text{Art} \\ +\text{Def} \\ \cdot \\ \cdot \\ \cdot \end{bmatrix} \begin{bmatrix} +N_c \\ +\text{Conc} \\ \cdot \\ \cdot \\ \cdot \end{bmatrix}$	IMP($_s$ you will suppose [$_s$		
600	$\begin{bmatrix} +\text{Art} \\ +\text{Def} \\ \cdot \\ \cdot \\ \cdot \end{bmatrix} \begin{bmatrix} +N_c \\ +\text{Conc} \\ \cdot \\ \cdot \\ \cdot \end{bmatrix} \begin{bmatrix} +\text{Prep} \\ +\text{Poss} \\ \cdot \\ \cdot \\ \cdot \end{bmatrix}$	. . . suppose [$_s$ the eye ($_s$	səp^{h}ōwz	

Table 1 (Continued)

Msec	Level of Processing: Lexical Entries	Level of Processing: Semantic Representation	Level of Processing: Phonetic Representation	Vocalization
700	$\begin{bmatrix}+\text{Prep}\\+\text{Poss}\\ \vdots\end{bmatrix}\begin{bmatrix}+\text{Art}\\-\text{Def}\\ \vdots\end{bmatrix}$	. . . the eye (${}_s$ X [${}_s$	ōwzðiyáy	"Su . . ."
800	$\begin{bmatrix}+\text{Prep}\\+\text{Poss}\\ \vdots\end{bmatrix}\begin{bmatrix}+\text{Art}\\-\text{Def}\\ \vdots\end{bmatrix}\begin{bmatrix}+\text{Adj}\\+\text{Deg}\\ \vdots\end{bmatrix}$	. . . eye (${}_s$X [${}_s$] has eye	zðiyáyəv	". . . ppo . . ."
900	$\begin{bmatrix}+\text{Prep}\\+\text{Poss}\\ \vdots\end{bmatrix}\begin{bmatrix}+\text{Art}\\-\text{Def}\\ \vdots\end{bmatrix}\begin{bmatrix}+\text{Adv}\\+\text{Deg}\\ \vdots\end{bmatrix}$	. . . X [${}_s$ X be Y (${}_s$Y mod)	ðiyáyəv	". . . se . . ."
1000	$\begin{bmatrix}+\text{Art}\\-\text{Def}\\ \vdots\end{bmatrix}\begin{bmatrix}+\text{Adv}\\+\text{Deg}\\ \vdots\end{bmatrix}\begin{bmatrix}+\text{Adj}\\+\text{Anim}\\ \vdots\end{bmatrix}$	. . . X be skilled (${}_s$skil . . .	áyəvə	". . . se . . ."

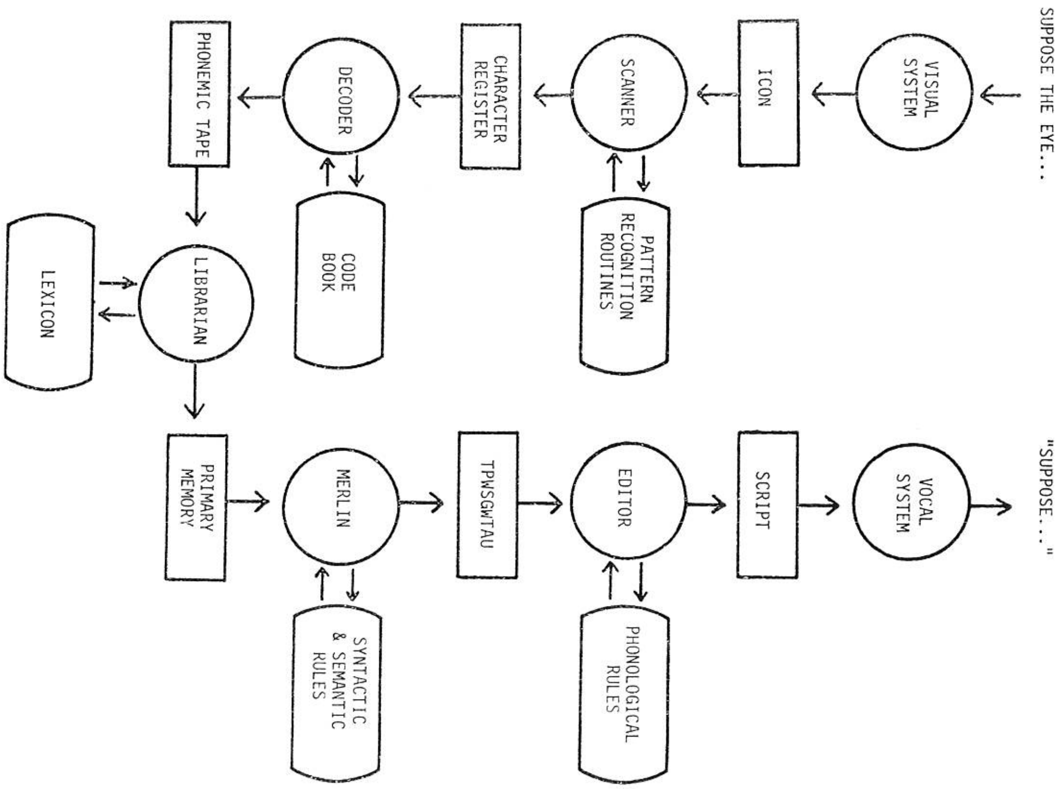

Figure 1. A model of reading.

THE ACQUISITION OF READING

The child comes to the task of learning to read with several of the necessary components, or at least with crude versions of them.

Obviously, he comes with a visual system, and it produces an icon. Whether or not the child's visual image is comparable to the adult's is a fascinating question; so far as I know, we know too little of the quantity and quality of the child's icon to say. But there can be little doubt that he has one.

At the other extreme, the child clearly has the capacity to produce and understand sentences. He comes to school equipped with a lexicon, a comprehension device, and a phonological system; in terms of the present model, he incorporates a Librarian, a Merlin, and an Editor. None of these is as elaborate or extensive as they all will be when he reaches adulthood. His lexicon obviously contains fewer entries than it will, and there are indications that the entries it has are not as complete as they will be [cf. McNeill 1970, Chapter 8]. His comprehension device (or at least the grammar it draws upon) is not that of an adult; there are a variety of syntactic structures which he does not yet reliably process [Berko 1958; C. Chomsky 1969]. His phonological component, at least as it is engaged in speech production, is likely to show considerable deviation from the adult norm.

But at the same time, none of these shortcomings precludes the assembly of (at least) a primitive reading machine, for the child can readily make use of what he has. What is lacking is a character recognition device (the Scanner) and the device which will convert the characters it yields into systematic phonemic representations (the Decoder).

Character Recognition

There is no doubt that character recognition poses a problem for the child. We know pitifully little about form perception in children [cf. Reese and Lipsitt 1970, Chapter 11]. But it seems clear that letters—"lank, stark, immovable, without form or comeliness, and as to signification, wholly void" [Mann 1841]—are not naturally identified. They can, of course, be discriminated [Caldwell and Hall 1969, 1970], but this is a far cry from the absolute identification demanded by the reading process. For example, while children will make relatively few mistakes in copying a pattern like a letter [Asso and Wyke 1971], indicating that they are quite capable of simultaneous discrimination, they find the same distinction inordinately difficult in a successive discrimination task [Rudel and Teuber 1963].

The difficulties posed for the child by letters that are mirror images of one another (e.g., "b–d, p–q") and, to a lesser extent, by those that are inversions (e.g., "b–p") have long been noted [cf. Monroe 1932]. There have been a number of studies assessing methods of teaching children these distinctions [e.g., Hendrickson and Muehl 1962]. And almost as often, this problem has been taken as a symptom of reading disability [cf. Orton 1937].

In one sense, it must be such a symptom. An inability to reliably identify "b" cannot fail to be a handicap in reading. But as E. Gibson has pointed out, the discrimination our orthography demands of the child runs directly counter to virtually all of his perceptual experience, in which objects differing only in orientation are equivalent. Moreover, Corballis and Beale [1971] have argued persuasively that such equivalence is deeply rooted in the bilateral symmetry of our anatomy. Thus these distinctions must pose a problem for every child, and there is every indication that this is the case.

Aside from orientation, the features that distinguish (or fail to distinguish) one letter from another in the child's icon are little understood. Gibson's studies of letter confusions in early readers and adults [Gibson, Schapiro, et al. 1968] have suggested a set of features that may well be those used by the character recognition device. What remains to be disclosed, however, are the features by which the prereader will distinguish the same patterns. This knowledge would indicate which sub-components of the character recognition device are available in the prereader, and which are not, and we might get some idea of what it takes to assemble the complete device.

It would be comforting to think that character recognition (or better, the lack of it) was the chief impediment to learning to read, for it can be taught (at least with patience). The unwary might be tempted to find support for this in the infamous fact that knowledge of the alphabet is the single best predictor of reading achievement [Bond and Dykstra 1967]. But Samuels [1971] has reported the results of several studies that found no evidence that teaching the alphabet facilitates learning to read.

It remains to be seen, however, if the correlation is entirely spurious.

Teaching of the alphabet, the ABC's, dates at least to the time of Socrates [Mathews 1966], and I find it difficult to believe that a tradition that appears to serve no other purpose would survive if it did not serve this one. Whether by means of alphabet books, blocks, or soup, character recognition must be mastered. It is obviously a necessary component of reading; equally obvious, it is not a sufficient one. Given character recognition, the fundamental problem arises, that which is commonly referred to as *decoding*.

Decoding

The Reader converts characters into systematic phonemes; the child must learn to do so. The Reader knows the rules that relate one set of abstract entities to another; the child does not. The Reader is a decoder; the child must become one. The decoding metaphor is familiar, and it would be difficult to argue that it is inappropriate. But if we take seriously the notion that characters are decoded to systematic phonemes, there is an interesting consequence. We can no longer think of the child as a clerk to whom we hand the code, for there is no direct way to display the rules constituting it. We cannot show him that this character goes with that systematic phoneme, for there is no way to isolate a systematic phoneme. We cannot tell him, "This goes with That," for we have no way of representing That.

In short, we cannot teach him the code. This is not to say that he cannot acquire it; every Reader before him has done so. But the child must master the code through a sort of cryptanalysis rather than through memorization. Viewed in this light, what is necessary for the child to learn to read is that he be provided with a set of pairs of messages known to be equivalent, one in ciphertext (writing) and one in plaintext (speech). They must be provided in sufficient quantity to enable him to arrive at a unique solution, and that is all.

A full solution of the code (i.e., one equivalent to that we ascribe to the Reader) can be achieved only if the child correctly identifies the alphabets of the plaintext and of the ciphertext. If we assume that the child has lexical representations in the form of systematic phonemes, the former should pose no special problem. (There is, however, some evidence to suggest that this may be a facile assumption; cf. Savin in this volume. It remains to be seen whether evidence of this sort is indicative of a different sort of phonological organization in the child, or the result of something much more superficial.)

If the child has mastered the character recognition problem as discussed above, then he has isolated the alphabet of the ciphertext, and his problem is reduced to a tractable one: that of searching for correspondences between the message pairs. But if, for some reason, he has not realized the unity of the letters, then he is faced with a cryptanalytic task of demonstrably greater difficulty, that of working out the cipher alphabet and the code simultaneously. In this connection, the Look-and-Say method obviously comes to mind. In light of the present analysis this method is not totally unreasonable. It provides the essential ingredients for the child's cryptanalysis (i.e., pairs of spoken and written messages). The trouble with it is that it does not appropriately define the problem for the child-cryptanalyst.

The Look-and-Say method confronts the child with a problem of paired-associate (PA) learning. We know that subjects confronted with the PA task will "solve" it as efficiently as they can; they will select some cue, some feature of each stimulus, and associate the defined response with that cue. That cue can be any feature or property of the stimulus item that distinguishes it from the others; in the case of visual material, it might be length, or area, or the presence of a curved line. I know of no reason to suppose that the child is different from the sophomore subject in this respect. Confronted with a word (the Look) to which he must associate a response (the Say), he should be likely to seize upon any feature of the word that differentiates it from the others he must master.

An egregious example of this can be found in a study reported by Coleman (1970) as part of his effort to collect a data base for a technology of reading. One of Coleman's concerns was to rank words that might be used in basic reading programs in order of the ease with which the child could learn to read them. So several hundred words were taught to different children by the look-say method, and the number of errors to criterion was taken as the basic datum. The words *kitten* and *o* were found to be the easiest of all. When it is noted that the words were presented in short lists, and that *kitten* is the only word as long as six letters, it is easy to see why these words were easy (and it is not that they are intrinsically so).

Given the manner in which lists are learned, it seems clear that the Look-and-Say method would not force the child to map characters onto phonemes until simpler strategies will no longer work, and that will not happen until the list reaches a substantial length. At this point, we would expect that some children will tackle the cryptanalysis and learn to read, but we should not be surprised to see others resign in frustration. And that, of course, is what is known to happen with the Look-and-Say method.

It is clearly preferable to confront the child with the mapping problem from the start, and to suggest to him that is solvable. One way is through phonics. In this method (or better, class of methods), the child is explicitly directed to the ciphertext alphabet, and conceivably to the plaintext as well. The method requires that he pair letters (and clusters of letters) with spoken syllables; to the extent that he segments those syllables, such learning might provide material for the necessary cryptanalysis.

It is important to realize, though, that phonics does not teach the mapping required to become a Reader. What the Reader knows is the mapping between characters and systematic phonemes; what the child is taught in phonics is to name a letter (or letter pair) with a syllable that contains the appropriate systematic phoneme. When a child "sounds out" a new word, it is apparent to any auditor that the child is not converting letters into underlying phonemic representations. Rather he is searching for something that he can hear as a word.

In the present analysis, phonics is not a method of teaching the child grapheme-phoneme correspondence rules. The rules he learns are not the rules he must master, but rather heuristics for locating words through the auditory modality. The lexical representations of those words then provide data for the induction of the real character-phoneme rules. Skill in phonics gives the child a means of naming a word *in loco parentis*; it provides him with a valuable means of data collection.

The crucial variable in the cryptanalytic problem is the character of the data: the nature and number of message pairs. Other things equal, the shorter the messages, the fewer the potential solutions; so cryptanalysis is facilitated if the shortest possible messages are provided first. Virtually every method takes advantage of this fact by beginning reading instruction with short words. (It is interesting to note that Jacotot, one of the intellectual ancestors of Gestalt psychology, advocated beginning with a book and gradually working back to the letter, whatever that means; Mathews [1966].) Cryptanalysis is also facilitated if the messages are arranged such that covariation is apparent; if a change in a ciphertext is also accompanied by a change in the corresponding plaintext, the solution is obvious.

From this perspective, the various so-called Linguistic Methods (like those advocated by Bloomfield [1942] and Fries [1963]) appear to be optimal, for they offer the child a sequence of message pairs in which only one element is varied at a time. What is surprising, at least on first inspection, is that this method has not been shown to be superior. Indeed, there is no compelling evidence that any reasonable method of reading instruction yields results different from the others. This is encouraging, in one sense, for it means that children can manage to learn to read under any method, so long as they are provided the appropriate data, and the present hypothesis predicts just that. But it is also frustrating, for differential predictions are the stuff of which theories are made.

The trouble is, of course, that Methods are not methods. That is, a Method describes little more than an orientation on the part of a teacher, and perhaps the use of a particular basal reading series [Chall 1967]. What are desperately needed are experimental studies of reading acquisition in detail, where we know what was presented to the child, when, in what manner, and how often.

There have been very few, and they are not very revealing. The first (that I know of) was conducted by Bishop [1964], using adult subjects. It was intended to compare the transfer effects of word and letter training. One group of subjects was taught an eight-item paired-associate list, where each stimulus consisted of four Arabic characters (e.g., و ں ا ڧ) drawn from a set of twelve, and each response was a disyllabic Arabic word (e.g., /faru/). A second group was taught to name each of the twelve characters with its appropriate phoneme (i.e., they were given instruction in Arabic phonics). A third learned an irrelevant task. When all groups were then asked to learn a new eight-item PA list (in which the characters were recombined to form novel words), the phonics group learned it most rapidly. This is scarcely surprising (though it may have been when the study was conducted), for it seems clear that the whole-word group had little reason to detect correspondences, since other strategies requiring no intellectual effort would suffice perfectly well. (In fact, we might have expected to see negative transfer in this group, save for the fact that training and transfer stimuli had no initial characters in common.) What is more interesting is that the word group performed better than the control; some subjects evidently took on the cryptanalysis even though it was not necessary. But these subjects were college students, and it is not obvious that children would go to the same trouble.

A more promising study was conducted with kindergarteners by Jeffrey and Samuels [1967]. They employed an artificial alphabet of six nonsense figures. Three (call them A, B, C), were identified with the consonants /m, s, b/, three (X, Y, Z) with the vowels /e, i, o/. One group of subjects, the Word Group, was taught a four-item PA list: AX–/mo/, BX–/so/, CY–/be/, CZ–/bi/. A Letter Group was taught four isolated correspondences: A–/m/, B–/s/, Y–/e/, and Z–/i/. A control group was taught an unrelated task.

Prior to training, all groups were familiarized with the alphabet, and given practice on "blending" the sounds to be used in the ultimate transfer list, AZ, BZ, BY, and AY. Then each group was given its training. On the transfer list, the phonics group performed significantly better than the others, which did not differ. In this study, the Letter Group was given what amounts to phonics instruction, and the Word Group might be thought of as representing a linguistic method. If this were so, the phonics instruction would seem to be the superior method of (at least) initial instruction. But there is a serious flaw in this analogy, for the Word Group was mistreated.

The Letter Group was exposed to just those four elements that would be involved in the transfer; the Word Group, on the other hand, confronted items composed of six. But more important, the organization of those elements fell short of that which could be expected to yield successful cryptanalysis.

The message pairs which the Word Group was allowed to use may be arranged in a matrix, arrayed by initial and final ciphertext element:

	X	Y	Z
A	/mo/	—	—
B	/so/	—	—
C	—	/be/	/bi/

This display makes clear the structure of the correspondence rules, and it is conceivable that they might be induced by someone who knew that CY can be decomposed to C and Y, and that /be/ consists of /b/ plus /e/. (In fact, the Word Group produced something like eight correct responses—of a possible 80—on the initial transfer trial, so more than one of the 20 must have induced something.) But there is nothing to demand it, for memorizing only four item-item correspondences will solve the problem. In fact, to achieve the solution of the code implicit in this matrix would require the identification of *six* rules. It is surely reasonable for the learner to prefer rote memory in this instance.

Such considerations lead to the hypothesis that the child would most readily learn the true system of correspondences when it provides the simplest solution to the cryptanalytic problem. For example, if, in a design like that of Jeffrey and Samuels, the child had been forced to learn not just four items, but all six lying outside a diagonal of this matrix, then the principled solution would be as simple as the associative one, and we would expect significantly greater transfer to novel items (i.e., the diagonal items).

This analysis suggests that the childs' task bears a striking resemblance to those studied in adults under the rubric of miniature linguistic systems. Since the seminal experiments of Esper [1925, 1933] this literature has grown too large to review here (see Smith and Braine, in press). But it provides abundant evidence for the principle proposed here: the greater the advantage afforded by induction of structure (over rote memory), the more frequent the induction. In the present case, we should expect to see that if Jeffrey and Samuels had not only more completely filled the matrix but enlarged it (in either dimension), the Word Method would have yielded dramatically better results [cf. Foss 1968; Palermo and Parrish 1971]. And when one considers that the real task confronting the child involves a matrix in multiple dimensions, the consequences are even more apparent.

There have been other studies of teaching methods [e.g., Hartley 1970]—in this experimental sense—but they add little to this picture.

How the child solves the decoding problem is a mystery, but many do. If one does, he should be able to understand and produce any word that conforms to the rules he has mastered. Yet it has long been observed that there are children who can read and pronounce words, children who can decode, but yet do not seem to *read* connected discourse. They "bark at print"; they are "word-callers" or "parrotreaders." Evidently, solving the decoding problem does not automatically make the child a Reader.

The Speed Problem

There is a natural interpretation of this problem within the present model. To understand a sentence, it does not suffice to obtain lexical entries, place them in the PM, and pronounce them. If the words of a sentence are to be integrated into a semantic reading, they must be deployed in the PM together.

To be sure, we adults can tolerate substantial delays between words without apparent disruption of comprehension; if the delays are brief enough, as in hesitation pauses, we may not even be aware of them. This is to be expected if the PM is indeed the repository for material waiting to be understood, for it will hold that material for a short while. But Martin [1968] has shown that pauses of as little as two seconds interfere with our ability to perceive sentences in noise, and we have found some evidence in pilot studies that repetition of words within sentences reduces our capacity to remember them.

It seems reasonable to suppose that the child's ability to comprehend sentences is affected in the same way. Furthermore, if—as some evidence suggests [Haith, Morrison, et al. 1970]—the child's PM is much smaller than our own, then pauses between words will prove even more disruptive for the child's comprehension. There is an obvious source of pauses in reading sentences: if words are identified slowly, then pauses are inevitable. There is abundant evidence that children do not identify words as rapidly as adults, and that the poor reader does not identify words as rapidly as the good one.

The hypothesis that temporal word spacing will significantly diminish sentence comprehension in the child would be easy to test. But I think that naturalistic observation of children reading aloud suggests that temporal spacing is a ubiquitous problem in early reading. If it takes too long to read a given word, the content of the immediately preceding words will have been lost from the PM, and comprehension will be prevented. If the word in question is read aloud, it will necessarily be read as a citation form, and the child's oral reading will sound like a list just because he is, in fact, reading a list.

To prevent this, the child who would understand must try to read rapidly, and if he cannot quickly identify a word, he must guess. The result will frequently be an oral reading error. These errors have been the subject of considerable study [Weber 1968], and seemingly contradictory conclusions have been drawn from them. On the one hand, it has been argued (e.g., by Goodman [1970] and elsewhere) that reading is normally a kind of guessing game, in which the reader uses the printed word for little more than hints as to whether he is thinking the right thoughts or not. In this view, oral reading errors are nothing but a manifestation of normal function, not a symptom of malfunction, and thus they should not be squelched. On the other hand, it has been argued (by Biemiller [1970]), that at least in the early stages of reading, oral reading errors are an indication that the child is avoiding the decoding problem, and thus a sign that he is unable to identify what lies before him.

From the present point of view, Biemiller is closer to the truth. A guess may be a good thing, for it may preserve the integrity of sentence comprehension. But rather than being a sign of normal reading, it indicates that the child did not decode the word in question rapidly enough to read normally. The good reader need not guess; the bad should not guess.

In the model I have outlined, the Reader is not a guesser. From the outside, he appears to go from print to meaning as if by magic. But I have contended that this is an illusion, that he really plods through the sentence, letter by letter, word by word. He may not do so; but to show that he does not, his trick will have to be exposed.

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The Typographic Element in Cubism, 1911–1915: Its Formal and Semantic Implications

Susan Marcus

Between 1911 and 1915 Braque and Picasso experimented with formal considerations of the typographic element. The two-dimensional quality of alphabetical and numerical symbols complemented the artists' attempt to find a new means for depicting three-dimensional objects within the format of the canvas. The typographic element assisted in the evolution of collage by encouraging the replacement of painted symbols with actual objects pasted to the canvas. The idea of a letter-word-number form as a sign representing a concept to which the sign bears no physical resemblance also provided semantic implications that these artists explored. In working with the typographic element, the Cubists acknowledged a common interest shared with contemporaries in literature and science.

In 1911 when George Braque stencilled a few letters, numbers, and an ampersand on the painting, *Le Portugais*, he introduced into Cubism the typographic element that ultimately served as a catalyst for the discovery of collage and for the evolution of its corollaries: the concept of the autonomous, constructed work of art, and the notion of the communicative qualities of the medium itself (Fig. 1). Through the typographic element, Braque also aided himself and Pablo Picasso in solving certain formal and semantic problems they faced at the time.

Typography is defined as the character and appearance of printed symbols. In Cubist paintings, the typographic element usually takes the form of letters, numerals, symbols, and printed material stencilled or painted free-hand on the canvas. With the medium of collage, printed material such as newspaper, bottle labels, musical scores, cigarette packages, and the like are pasted to the canvas. Whatever their form, these elements function within Cubist painting and collage of the years 1911 to 1915 as formal pictorial and compositional motifs, while also contributing to the iconographic or semantic program of Cubism.

Visible Language, VI 4 (Autumn 1972), 321–340

Author's address: 5y Magie Apts., Faculty Road, Princeton, N.J. 08540.