COGNITIVE PSYCHOLOGY 6, 293–323 (1974)

Toward a Theory of Automatic Information Processing in Reading[1]

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A model of information processing in reading is described in which visual information is transformed through a series of processing stages involving visual, phonological and episodic memory systems until it is finally comprehended in the semantic system. The processing which occurs at each stage is assumed to be learned and the degree of this learning is evaluated with respect to two criteria: *accuracy* and *automaticity*. At the accuracy level of performance, attention is assumed to be necessary for processing; at the automatic level it is not. Experimental procedures are described which attempt to measure the degree of automaticity achieved in perceptual and associative learning tasks. Factors which may influence the development of automaticity in reading are discussed.

Among the many skills in the repertoire of the average adult, reading is probably one of the most complex. The journey taken by words from their written form on the page to the eventual activation of their meaning involves several stages of information processing. For the fluent reader, this processing takes a very short time, only a fraction of a second. The acquisition of the reading skill takes years, and there are many who do not succeed in becoming fluent readers, even though they may have quickly and easily mastered the skill of understanding speech.

During the execution of a complex skill, it is necessary to coordinate many component processes within a very short period of time. If each component process requires attention, performance of the complex skill will be impossible, because the capacity of attention will be exceeded. But if enough of the components and their coordinations can be processed automatically, then the load on attention will be within tolerable limits and the skill can be successfully performed. Therefore, one of the prime issues in the study of a complex skill such as reading is to determine how the processing of component subskills becomes automatic.

[1] This research was supported by a grant (HD-06730-01) to the authors from the National Institutes of Child Health and Human Development, and in part by the Center for Research in Human Learning through National Science Foundation Grant GB-17590. Reprints may be requested from David LaBerge, Department of Psychology, University of Minnesota, Minneapolis, Minnesota 55455.

Our purpose in this paper is to present a model of the reading process which describes the main stages involved in transforming written patterns into meanings and relates the attention mechanism to processing at each of these stages. In addition, we will test the model against some experimental findings which indicate that the role of attention changes during advanced states of perceptual and associative learning.

This paper is divided into four sections in which we (1) briefly summarize the current views of the attention mechanism in information processing, (2) set forth a theory of automaticity in reading and evaluate it against some data, (3) discuss factors which may influence the development of automaticity, and (4) discuss some implications of the model for research in reading instruction.

ATTENTION MECHANISMS IN INFORMATION PROCESSING

In view of the fact that the present model places heavy emphasis on the role of attention in the component processes of reading, it may be well to review briefly the way the concept has been used by researchers in the recent past.

The properties of attention most frequently treated by investigators are selectivity and capacity limitation. Posner and Boies (1971) list alertness as a third component of attention, but this property has been investigated mostly in vigilance tasks and less often in the sorts of information processing tasks related closely to reading. The property of attention which has generated the most theoretical controversy is its limited capacity. When early dichotic listening experiments indicated that subjects select one ear at a time for processing messages, Broadbent (1958) proposed a theory which assumed that a filter is located close to the sensory surface. This filter allows messages from only one ear at a time to get through. However, later experiments indicated that well-learned significant signals such as one's own name (Moray, 1959) managed to get processed by the unattended ear. This led Treisman (1964) to modify the Broadbent theory and allow the filter to attenuate the signal instead of blocking it completely. In this way, significant, well-learned items could be processed by the unattended ear. Deutsch and Deutsch (1963), on the other hand, described a theory which rejected the placement of a selective filter prior to the analysis or decoding of stimuli and instead placed the selection mechanism at a point much later in the system, after the "importance" or "pertinence" (Norman, 1968) of the stimulus has been determined.

In the present model, it is assumed that all well-learned stimuli are processed upon presentation into an internal representation, or code, regardless of where attention is directed at the time. In this regard, the model is similar to the models of Deutsch and Deutsch and of Norman.

However, the present theory proposes in addition that attention can selectively activate codes at any level of the system, not only at the deeper levels of meaning, but also at visual and auditory levels nearer the sensory surfaces. The number of existing codes of any kind that can be activated by attention at a given moment is sharply limited, probably to one. But the number of codes which can be simultaneously activated by outside stimuli independent of attention is assumed to be large, perhaps unlimited. In short, it is assumed that we can only attend to one thing at a time, but we may be able to process many things at a time so long as no more than one requires attention.

It is this capability of automatic processing which we consider critical for the successful operation of multicomponent, complex skills such as reading. As visual words are processed through many stages en route to meaningfulness, each stage is processed automatically. In addition, the transitions from stage to stage must be automatic as well. Sometimes a stage may begin processing before an earlier one finishes its processing. Examples of these interrelations between stages of processing are treated in the research of Sternberg (1969) and Clark and Chase (1972). In the skill of basketball, ball-handling by the experienced player is regarded as automatic. But ball-handling consists of subskills such as dribbling, passing, and catching, so each of these must be automatic and the transitions between them must be automatic as well. Therefore, when one describes a skill at the macrolevel as being automatic, it follows that the subskills at the microlevel and their interrelations must also be automatic.

Our criterion for deciding when a skill or subskill is automatic is that it can complete its processing while attention is directed elsewhere. It is especially important in such tests that one take careful account of all attention shifts. On many occasions, people appear to be giving attention to two or more things at the same time, when, in fact, they are shifting attention rapidly between the tasks. An example is the cocktail party phenomenon in which a person may appear to be following two conversations at the same time, but in reality he is alternating his attention.

The way we attempt to manage this problem in the laboratory is to test automaticity with procedures that control the momentary attention state of the subject (LaBerge, Van Gelder, & Yellott, 1970). Typically, we present a cue just prior to the stimulus the subject is to identify, and this induces a state of preparation for that particular stimulus. Most of the time he receives the expected stimulus, but occasionally he receives instead a test stimulus unrelated to the cue. The response to the unexpected test stimulus requires that the subject switch his attention as well as process the test stimulus. If the processing of the test stimulus requires attention, then the response latency will include both time for stimulus processing and time for attention switching. If, however, the stimulus processing does not require attention (i.e., it is automatic), then the response latency will not include stimulus processing time, assuming that the stimulus processing is completed by the time attention is switched.

MODEL OF AUTOMATICITY IN READING

With these considerations of attention in mind, we turn to a description of a model of automatic processing in reading. This model is based on the assumption that the transformation of written stimuli into meanings involves a sequence of stages of information processing (Posner *et al.*, 1972). Although the overall model has many stages and alternative routes of information processing, we hope that the way it is put together will permit us to isolate small portions of the model at a time for experimental tests without doing violence to the model regarded as a whole. Our strategy here is to capture the basic principles of automaticity in perceptual and associative processing with simple examples drawn from initial processing stages of reading and then indicate how these examples generalize to more complex stages of reading.

We shall consider first the learning, or construction, of visual codes in reading, which includes the perception of letters, spelling patterns, words, and word groups. After presenting some relevant data, we will attempt to detail the rest of the model, showing how the visual stage fits into the larger picture. Then we will describe an experiment which attempts to demonstrate the acquisition of automaticity in the kind of associative learning utilized in the decoding and simple comprehension of words.

Model of Grapheme Learning

Now let us consider in some detail the learning of a perceptual code. It is assumed that incoming information from the page is first analyzed by detectors which are specialized in processing features such as lines, angles, intersections, curvature, openness, etc., as well as relational features such as left, right, up, down, etc. (Rumelhart, 1970). For present purposes, it is not necessary that we stipulate the exact mapping of these features onto properties of physical stimuli. In fact, to do so would emphasize a punctate view of the feature detectors, whereas we wish to provide for the possibility, following Gibson (1969), that relational aspects may be important in this kind of learning. However, it should be pointed out that it is sometimes difficult to define relational properties in a clear way.

In Fig. 1 we present an abbreviated sketch of the role of visual

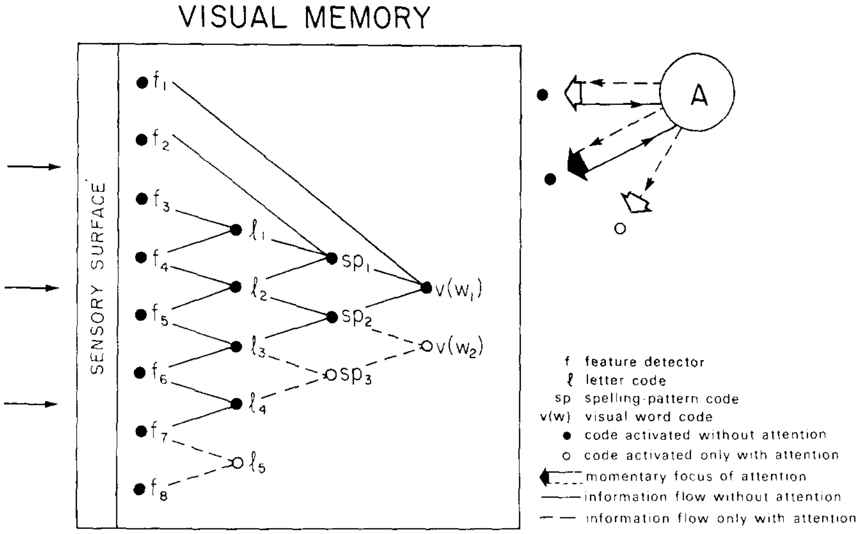

FIG. 1. Model of visual memory showing two states of perceptual coding of visual patterns. Arrows from the attention center (A) to solid-dot codes denote a two-way flow of excitation: attention can activate these codes and be activated (attracted) by them. Attention can activate open-dot codes but cannot be activated (attracted) by them.

perception in the reading model. In this schematic drawing, graphemic information enters from the left and is analyzed by feature detectors, which in turn feed into letter codes. These codes activate spelling-pattern codes, which then feed into word codes, and word codes may sometimes give rise to word-group codes. Some features activate spelling patterns and words directly (e.g., f_1 and f_2). These features detect characteristics such as word shape and spelling-pattern shape. This hierarchical coding scheme draws heavily on the notions of Gibson (1971), Bower (1972), Johnson (1972), and others, but particularly on the model described by Estes (1972).

The role of the attention center of Fig. 1 is assumed to be critical early in the learning of a graphemic code, but expendable in later states of learning. Arrows from the attention center indicate a two-way flow of information between the center and each visual code in long-term memory. Every visual code in long-term memory is represented by the symbol ○ or ●. The open circle indicates codes that are activated only with the assistance of attention. The filled circles indicate codes which may be activated without attention. The lines leading from the visual codes to attention represent the flow of information that occurs when a code has been activated or "triggered" by stimuli. The lines leading from the attention center to visual codes represent the activation of these units by attention. When a stimulus occurs and activates a code, a signal is sent to the attention center, which can "attract" attention to that code unit in the form of additional activation. Only the well-learned, filled-circle codes can attract attention. If attention is directed elsewhere at the time a visual code is activated by external stimulation, attention will not shift its activation to that visual code, unless the stimulus is intense or unless the code automatically activates autonomic responses or other systems which mediate the "importance" (Deutsch & Deutsch, 1963) or "pertinence" (Norman, 1968) of that code to the attention center.

The many double arrows emanating from the attention center, therefore, indicate potential lines of information flow to every well-learned code in visual long-term memory. At any given moment, however, the attention center activates only one code. This characteristic of the model represents the limited-capacity property of attention.

As conceptualized here, attentional activation may have three different effects on information processing. First of all, it can assist in the construction of a new code by activating subordinate input codes. For example, in Fig. 1, successive activation of features f_7 and f_8 is necessary to synthesize letter code l_5. Secondly, activation of a code prior to the presentation of its corresponding stimulus is assumed to increase the rate of processing when that stimulus is presented (LaBerge *et al.*, 1970). Finally, activation of a code can arouse other codes to which it has been associated, as will be described later in connection with Fig. 3.

Some of the most common patterns we learn to recognize are letters, which are represented in Fig. 1 as l_1, l_2, etc. We assume that the first stage of this learning requires the selection of the subset of appropriate features from the larger set of features which are activated by incoming physical stimuli. For example, assume that a child is learning to discriminate the letters *t* and *h*. The length of the vertical line is not relevant to the discrimination of these two letters. Instead he must note the short horizontal cross of the *t* and the concave loop in the *h*. These are the distinctive features of these letters when considered against each other. In the model, we represent the selection of features of a given letter by the lines leading from particular features to a particular letter. In this example, the length of the vertical line is an irrelevant feature, but when these two letters are compared with other letters, for example the letter *n*, the length of the vertical line becomes a relevant feature. We assume that this kind of adjustment in feature selection continues as the rest of the alphabet is presented to the child. One feature that seems to be irrelevant for all letters is thickness of line. It would appear, then, that many features are selected for a given letter, and in many cases letters share features in common. Therefore, the relationship between the feature and letter code levels shown in Fig. 1 is somewhat simplified for economy of illustration. Figure 1 shows only two lines leading from features into a given letter; typically a letter is coded from more than two feature detectors, and a given feature may feed into more than two letters.

As a first stage of perceptual learning, selection of relevant features is similar to the initial stages of concept learning tasks (e.g., Trabasso & Bower, 1968) in which the subject searches for the relevant dimension before he selects a response. The rate of learning to select the appropriate features of a pattern may be quite slow the first time a child is given letters to discriminate. However, after a child has experienced several discrimination tasks, he may develop strategies of visual search which permit him to move through this first stage of perceptual learning at an increasingly rapid rate.

In the second stage of perceptual learning, as conceived here, the subject must construct a letter code from the relevant features, a process which requires attention. By rapid scanning of the individual feature detectors, perhaps along with some application of Gestalt principles of organization (e.g., proximity and similarity), a higher-order unit is formed. If the pattern has too many features, organization into a unit code might not be manageable. This would mean that when the letter is itself organized into a superordinate code, it would consist of several components, instead of one unit. However, when the features do permit organization into a unitary code, this code is of a short-term nature at first and is quickly lost when the eye shifts to other patterns, or when attention activates another visual code. But every time the subject organizes the features into that particular letter code, some trace of this organization between features and letter code is laid down. The dashed lines in Fig. 1 between features and a letter represent the early state of establishment of these traces, and the solid lines represent later states of trace consolidation.

In the early trials of learning we assume that attention activation must be added to external stimulation of feature detectors to produce organization of the letters into a unit. In the later trials, we assume that features can feed into letter codes without attentional activation, in other words, that the stimulus can be processed into a letter code automatically.

For example, contrast the perception of the familiar letter *a* with the unfamiliar Greek letter γ. Let us assume that the visual stimulus, *a*, first activates the feature detectors f_3 and f_4. These features automatically activate the letter code l_1, which corresponds to the letter *a*. When the Greek letter, γ, is presented, assume that features f_7 and f_8 are activated. However, these features do not excite the letter code l_5 by themselves.

Nevertheless, when this unfamiliar letter is presented, the feature detectors f_7 and f_8 induce the attention center to switch attention activation to themselves, because they are already linked to the attention center (by learning or heredity). The resultant scanning or successive activation of these features by attention produces sufficient additional activation to organize and arouse the letter code l_5. Were the subject to activate and not organize the features, then the Greek letter would not be perceived as a unit but merely as a set of features, f_7 and f_8.

If the subject is induced to organize the separate features into a unit when it is presented to him, the lines linking features f_7 and f_8 will presumably become strengthened, until after many such experiences they eventually become as strong as those lines linking features f_3 and f_4 with letter code l_1, which represents a highly familiar pattern such as the letter *a*. When this is accomplished, the Greek letter, γ, can be perceived as a unit without requiring attention to the scanning of its component features.

When this unitization becomes automatic, there is nothing to prevent the subject from exercising the option of attending to the features of the Greek letter, much as he can choose to pay attention to the curved lines in the familiar letter *a* if he chooses. This optional attentional activation at either the feature level or the letter level is implied in the model by the placement of dots at both feature detectors and letter codes.

At this point it would appear appropriate to mention that there may exist another stage of learning located between feature selection and the unitizing stages of perceptual learning. Quite possibly the subject may learn to scan features more rapidly with practice, and eventually the scanning itself may become automatic. Experiments which measure the learning of patterns by shortened reaction time in matching tasks or by increased accuracy in tachistoscopic exposures would then be revealing the learning of a scanning path for features and not necessarily the gradual formation of a unit. One way to test for feature scanning as opposed to unit formation might be to estimate how much short-term memory capacity is taken up when a letter is presented. For example, to identify each letter by a series of feature tests may require about four or five binary decisions (Smith, 1971), implying that each letter is represented by as many components. Even if a subject stores only three or four letters visually in short-term memory, this means he would have to be storing 12–20 feature chunks, which seems unlikely given the limits set by Miller (1956) at seven plus or minus two.

One might be tempted to move the argument up one level in the visual hierarchy and maintain that letters are the visual units normally coded in reading. This would leave the formation of higher-order units to other systems such as the phonological system. This position is close to the one taken by Gough (1972), who makes a strong attempt to reconcile letter-by-letter visual scanning with the apparently high rates of word processing by fluent readers.

One could even move the argument up another level to consider spelling patterns as the typical units of visual perception in reading, a position preferred by Gibson (1971), although she maintains that these units must eventually be reorganized into still higher-order units.

The critical point being made here is that automaticity in processing graphemic material may not necessarily mean that unitizing has taken place. Scanning pathways may have been learned to the degree that they can be run off automatically and rapidly, whatever the size of the visual code unit involved. The present model as depicted in Fig. 1 adapts itself to the view that a letter may be a cluster of discrete features which are scanned automatically. One simply equates the symbol l_1 with the term (f_3, f_4), to indicate that the code at the letter level is a cluster of feature units. The interpretation of automaticity is the same. For the dashed lines linking features with letters, the features cannot be adequately scanned without the services of attention; for the solid lines, the features are scanned automatically. For present purposes of exposition, however, we find it more convenient to refer to letters, spelling patterns, and words as unit codes, but we hope that the reader will keep in mind that there is an alternative view of what it is that is being automatized in perceptual learning of this kind.

Before extending the model to other stages of processing, such as sounding letters, spelling patterns, and words or comprehension of words, we will describe briefly an experiment which attempted to measure automaticity of perception and use it as an indicator of amount of perceptual learning of a graphemic pattern.

Indicators of automatic perceptual processing. One way to test recognition of a letter is to present two letters simultaneously and ask the subject to indicate if they match or not (Posner & Mitchell, 1967). In order to determine whether a person can automatically recognize a letter pattern, we must present a pair of patterns at a moment when he is not expecting them. The way this was done in a recent study (LaBerge, 1973b) was to induce the subject to expect a letter, e.g., the letter *a*, by presenting it first as a cue in a successive matching task. If the letter which followed the cue was also an *a*, he was to press a button, otherwise not. Occasionally, following the single letter cue *a*, the subject was given a pair of letters other than the letter expected, e.g., the stimulus (b b). If these letters matched, he was to press the button, otherwise not, regardless of what the cue was on that trial. In terms of Fig. 1, the state of the subject at the moment he expects the letter *a* may be represented by the attention arrow activating l_1, which we shall assume corresponds to the letter code *a*. The perceptual analyzers are primed to process the stimulus *a* and when it occurs, the speed of recognition should be increased. However, when a pair of different letters, (b b), is presented, corresponding to l_4, for example, the attention arrow leading to l_4 now becomes activated and the arrow to l_1 deactivated. The time required for this change is often referred to as switching time and may be as large as 80 msec in some cases (LaBerge, 1973a). The important prediction by the model is that familiar letters corresponding to l_4 will have already processed features f_6 and f_7 into the letter code l_4 by the time attention is switched from l_1 to l_4, whereas unfamiliar letters such as l_5 will not have achieved this capability of processing features f_7 and f_8 into l_5 before attention is switched to l_5.

Therefore our indicator of automaticity in the perception of a letter pattern is the extra time it takes to perceptually process a letter once attention has been shifted to that letter. If this time is negligible, then we conclude that the letter code is activated automatically from external stimulation of its features before attention was switched to it. If this time is substantial, then we conclude that attention was needed to synthesize the features into the letter code. Of course we do not have direct means of assessing the amount of attention time involved in perceptual coding. However, we do have good estimates of the total time it takes to code and match highly familiar letters in these tasks, which for adults we assume must be quite automatic by now. Using familiar letters as controls, we can measure the differences between match latencies for unfamiliar and familiar letters and use this as an estimate of the extra attention time required to process unfamiliar letters. Then, as further training is given, we may note the convergence of the latencies of the unfamiliar to the familiar letters and use this as an indicator of perceptual learning.

In the experiment by LaBerge (1973b), the unfamiliar letters were [⇂⇃↾↿] and the familiar letters used as controls were [b d p q]. Other groups of letter patterns, e.g., [a g n s], were used as cues to focus the subject's attention at the moment a pair of test letters was given according to the procedure just described. Referring to Fig. 1, a letter from the familiar test group could be represented by a letter code such as l_4, and a letter from the unfamiliar test group by l_5. A letter from the group [a g n s] could be represented by l_1, which represents the momentary focus of attention. We expected that latencies of unfamiliar test letter matches would be longer than the familiar letter matches at first, but we expected that the amount of the difference would decrease with practice if perceptual learning were taking place.

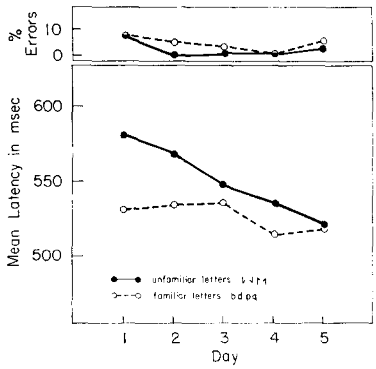

FIG. 2. Mean latency and percent errors of matching responses to unfamiliar and familiar letter patterns.

The results from the 16 college-age subjects are shown in Fig. 2. The initial difference in latency between unfamiliar and familiar letters was 48 msec and the difference clearly decreased over the next four days. In terms of the model in Fig. 1, we would say that the dashed lines between features f_7 and f_8 and l_5 were strengthened over days and approached the automatic level of learning of the lines connecting f_6 and f_7 with l_4.

The finding that unfamiliar letters improved with practice more than did familiar letters offers support for the hypothesis that something is being learned about the unfamiliar letters over the days of training. Evidence that subjects are learning automatic processing of the unfamiliar letters is supported by a special testing condition presented to another group of 16 subjects. In this condition, the familiar and unfamiliar patterns were presented both as cues and target stimuli so that we could assess the time taken to detect the letter when the subject expected that letter. In terms of the model in Fig. 1, we assume for the unfamiliar letter that the attention arrow to l_5 is activated at the time the letter is presented. Similarly, when a familiar letter, l_4, is cued, the attention arrow is focused on l_4 in preparation for that letter to be presented.

A comparison of latencies of these successive matches showed that the time to make an unfamiliar match equals the time to make a familiar match. This means that under conditions when the subject is attending to these letters, differences between perceptual learning of letters are not revealed. Only under conditions when the subject is attending elsewhere at the moment when the test letter is presented do these differences emerge.

Taken together, the data from these two conditions strongly suggest that what is being learned over days is a perceptual process that operates without attention, namely an automatic perceptual process. Whether the process be a unitizing one or a quick scanning of features, or perhaps something else, is not decided by these data. The main conclusion is that what is being improved with practice is automaticity.

Apparently, acquiring automaticity is a slow process in contrast to the relatively quick rate of acquiring accuracy in paired associate learning (Estes, 1970). For a five-year old, one suspects that achievement of automatic recognition of the 26 letters of the alphabet may indeed be a slow learning process, assuming that the child is no better than the college adult at this task. It may be that the child can learn to distinguish letters with accuracy with relatively few exposures, but it is costing him a considerable amount of attention to do it. Apparently, considerably greater amounts of exposure to the graphemes are necessary before the child can carry out letter recognition automatically, a feat he must learn to do if he is to acquire new skills involving combinations of these letters.

For other studies which support the hypothesis that visual processing may occur without attention, the reader is referred to Eriksen and Spencer (1969), Posner and Boies (1971), Egeth, Jonides, and Wall (1972), and Shiffrin and Gardner (1972). An experiment by LaBerge, Samuels, and Petersen (1973) treats perceptual learning of unfamiliar letter-like patterns which are more complex than the ones described here with similar results.

THEORETICAL RELATIONSHIPS BETWEEN VISUAL AND PHONOLOGICAL SYSTEMS

We turn now to a consideration of other processing systems which presumably operate on the inputs from visual codes. Of course the model we are describing step-by-step is not considered to be complete at this time. Rather we expect that it will have to be modified a good deal as the appropriate experimental tests are made. However, we hope that the present model will help clarify some of the locations of our ignorance and point the way to the kinds of experimental and theoretical operations most likely to remove that ignorance.

In Fig. 3 we describe the structure of the phonological memory system and the more important lines of associative activation, both direct and indirect, leading from the visual codes. Evidence that recognition of visually presented words typically involves phonological recoding is given by Rubenstein *et al.* (1971) and Wicklund and Katz (1970). A model of the articulatory response system is also briefly sketched to represent direct links between phonological memory and the overt articulation of words. The structures in the visual memory system are abbreviated in Fig. 3 for economy of exposition.

The phonological memory system is assumed to contain units closely

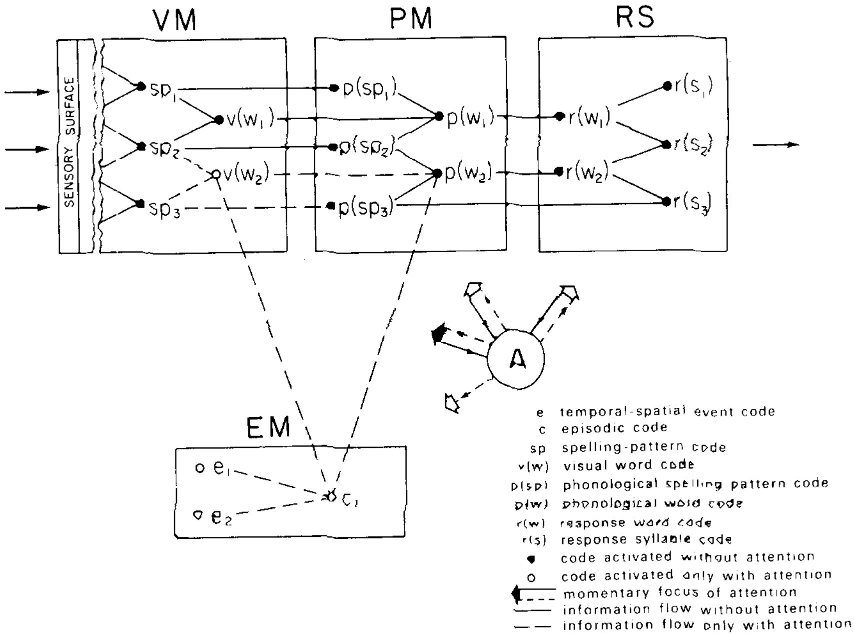

FIG. 3. Representation of associative links between codes in visual memory (VM), phonological memory (PM), episodic memory (EM), and the response system (RS). Attention is momentarily focused on a code in visual memory.

related to acoustic and articulatory inputs. If we were to represent these systems separately, we would be strongly tempted to construct the acoustic system in a fashion similar to the visual system, with features, phonemes, syllables, and words structured in a hierarchy. The structure of the articulatory system is roughly suggested within the response system of Fig. 3, in the form of a hierarchy of response output nodes arranged in a mirror image of the hierarchies for the sensory systems. For example, to respond with a word, one gives attention to $r(w_1)$ which then automatically feeds into the syllabic units $r(s_1)$ and $r(s_2)$, and perhaps from these into phonemes. For present purposes, we feel that we can trace the flow of information from the visual system to the phonological system without making specific assumptions about the precise relationships between the acoustic and articulatory systems. Following Gibson (1971), therefore, we lump these under the general heading of the phonological system.

The input to the phonological memory system is assumed to come from at least six sources: units in visual memory, response memory, semantic memory, and episodic memory, as well as from auditory stimulation and articulatory response feedback. Of course, additional activation can be provided from the attention center to any well-learned unit in phonological memory as is the case for units in visual memory. The sources of input of main interest here are the codes of the visual system. Associations between visual codes and their phonological counterparts are indicated by the lines drawn between the visual and phonological systems. Solid lines denote automatic associations; dashed lines denote associations that require additional activation by attention to generate an association. For example, a visually coded word $v(w_1)$, e.g., "basket," automatically activates its phonological associate, $p(w_1)$, e.g., /basket/, while another visual word code $v(w_2)$, e.g., "capstan," requires additional activation by attention before it can activate its phonological associate $p(w_2)$, e.g., /capstan/. Another way that the phonological code $p(w_1)$ can be activated by the visual system is by way of the component spelling patterns sp_1 ("bas") and sp_2 ("ket"), which may be associated with the phonological units $p(sp_1)$, (/bas/), and $p(sp_2)$, (/ket/). Once $p(sp_1)$ and $p(sp_2)$ are activated, they in turn activate and organize a blend into the phonological word unit, $p(w_1)$, (/basket/). This blend is accomplished by the two connecting lines presumably learned to automaticity by a great deal of practice in hearing and speaking these two syllabic components in the context of the word unit.

Thus we have specified two different locations in which the unitizing of a word might take place, one in the visual system and the other in the phonological system. For the experienced reader, the particular location used is optional. If he is reading easy material at a fast pace, he may select as visual units words or even word groups; if he is reading difficult material at a slow pace, he may select spelling patterns and unitize these into word units at the phonological level.

Exactly how these options are executed is a matter for speculation at present. Our best estimate of the role of the attention activator during fast reading is one in which no attention is given to the visual system, and the highest visual unit available is the one that automatically activates its corresponding phonological code. For slow reading, we suspect that the attention arrow is directed to the visual system where smaller units are given added activation, resulting in the activation of smaller phonological units. These phonological units then are blended automatically into larger phonological units.

The dashed lines in Fig. 3 leading to the episodic memory system represent an indirect way that a visual code may activate a phonological code. This memory system, labeled "episodic" by Tulving (1972), is closely related to the temporal-contextual-information store of Shiffrin and Geisler (1973). It contains codes of temporal and physical events which can be organized with visual and phonological codes into a superordinate code, indicated here by c_1. These codes represent associations that are in the very earliest stages of learning. The dashed lines connected with the episodic code represent the fact that attention is required to activate the code. With further practice, direct lines may be formed between visual and phonological codes, for example the line joining $v(w_2)$ with $p(w_2)$. This link is represented by a dashed line to indicate that additional activation by attention still is necessary for the association to take place. The solid lines joining visual and phonological codes, of course, represent well-learned associations that occur without attentional activation. Of course, all three types of associations, episodic, nonautomatic direct, and automatic direct, are assumed to be at the accuracy level.

The initial association between a new visual pattern and its phonological response is considered to be a fast learning process (Estes, 1970). It may not occur on the first trial, but when it does occur, it appears to happen in an all-or-none manner. For this state of learning, progress is indicated customarily by percent correct or percent errors. When the subject has achieved a criterion of accurate performance, the visual code still requires attention whenever retrieval occurs through the episodic memory code or through a direct dashed-line connection, even if the perceptual coding of the visual stimulus itself is automatic. Further training beyond the accuracy criterion must be provided if the association is to occur without attention, represented by the solid lines. The letter-naming experiment soon to be described will serve as an illustrative example of the associative learning this model is intended to represent.

THEORETICAL RELATIONSHIPS BETWEEN VISUAL, PHONOLOGICAL, AND SEMANTIC SYSTEMS

Once a visual word code makes contact with the phonological word code in reading, we assume that the meaning of the word can be elicited by means of a direct associative connection between the phonological unit, $p(w_1)$, and the semantic meaning unit, $m(w_1)$, as shown in Fig. 4. Most of the connections between phonological word codes and semantic meaning codes have already been learned to automaticity through extensive experience with spoken communications. In fact, authors of children's books purposely select vocabularies in which words meet this condition. This takes the attention off the processing of meaning and frees it for decoding. However, for a child in the process of learning meanings of words, we assume that the linkage between a heard word and its meaning may be coded first in episodic memory. This is represented in Fig. 4 by the organization of $p(w_3)$ and $m(w_3)$ and event e_1

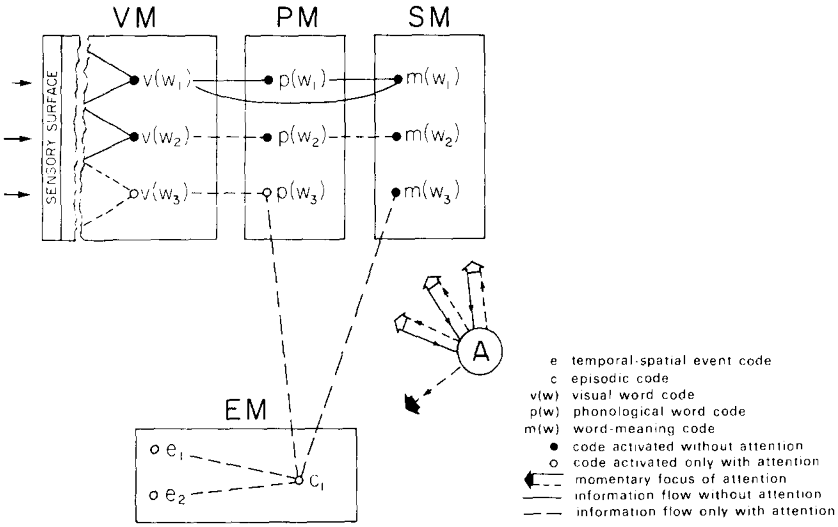

FIG. 4. Representation of three states of associative learning involving codes in visual memory (VM), phonological memory (PM), semantic memory (SM), and episodic memory (EM). Attention is momentarily focused on a code in episodic memory.

and e_2 into the episodic code c_2. Additional exposures to a word along with activations of its meaning would begin to form a direct link between the phonological unit and its meaning, represented by the dashed line between $p(w_2)$ and $m(w_2)$. At these two states of learning, attention is needed to activate the association of a heard word into its meaning, but with enough practice, a word should elicit its meaning automatically, as illustrated by the solid line joining $p(w_1)$ with $m(w_1)$.

At this point we may mention that the association between the phonological form of a word and its meaning may go in the other direction, so that activation of a meaning unit could automatically excite a phonological unit. However, we are not prepared to specify in any detail how this is done. We simply wish to indicate that generating speech by activation of semantic structures also appears to be automatic, at least in the general sense in which we are using the term here.

We should note the possibility in the model that a visual word code may be associated directly with a semantic meaning code (Bower, 1970; Kolers, 1970). That is, a unit, $v(w_1)$, may activate its meaning, $m(w_1)$, without mediation through the phonological system. The fact that we can quickly recognize the difference in the meaning of such homonyms as "two" versus "too" seems to illustrate this assumption.

Indicators of automatic associative processing. The way we are currently measuring the role of attention in associative processing is similar in principle to the method already described in this paper for testing automaticity of perceptual recognition. Here again, latency serves as the critical indicator, since we are interested in learning trends after the accuracy criterion has been met. The fact that response latency of a paired associate decreases considerably after accuracy has been achieved has been well-established by Millward (1964), Suppes *et al.* (1966), Judd and Glaser (1969), and Hall (1972).

In a test of automatic associative processing used by LaBerge & Samuels (1973), the subject is asked to name the letter he sees. In order to strictly control the subject's attention at the moment the letter appears, we give him another task to perform and then insert the letter at a moment when he does not expect it. Eight subjects observed pairs of common words presented successively and pressed a button when the second word matched the first word. Conditions were arranged so that the first word of each pair prepared the subject's attention for the following word. Occasionally, instead of presenting the same word for a match, we presented a letter and asked the subject to name it aloud into a microphone which activated a voice key. Since he expected to see a particular word at that moment, we could test how much of the letter-naming process was carried out before attention was shifted to the letter. Of course, this test of automaticity required a control condition with letters whose names were already at the automatic level of associative learning.

The two sets of letters were the same as the ones used in the perceptual learning study. The familiar set was [b d p q] and the unfamiliar set was [⇂⇃↾↿]. The names for the familiar set were bee, dee, pea, and cue, and the names for the unfamiliar set were one, two, four, and five. The overall latency of naming a letter pattern presumably includes perceptual coding time, association time, and residual response time. However, we were interested in differences only in association time. After determining that the residual-response component was equal for the familiar and unfamiliar letters, we had only to equate the familiar and unfamiliar letters with respect to perceptual coding time. To do this we gave the subjects preliminary training on perceptual matching of the unfamiliar patterns until they were recognized as fast as familiar patterns. These matching tests were given under automatic test conditions already described. When the criterion had been met on matching tests, the subjects were given a card for about two minutes on which were drawn the new patterns along with their corresponding names. They then began a series of daily tests of naming these new letters along with tests in which familiar letters were named. After each day's test block, intensive training blocks were given

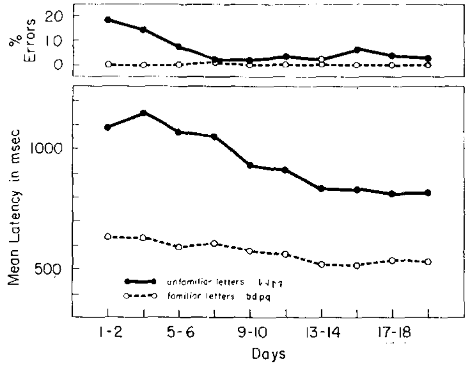

FIG. 5. Mean latency and percent errors of naming responses to unfamiliar and familiar letter patterns.

in which a trial consisted of a small circle as a cue followed by one of the eight letters which the subject named. Figure 5 shows the results of this experiment over 20 days of testing and training.

It is evident that the latency difference of a naming response to the new and old letters is quite large at first and converges over days of training. All eight subjects showed convergence. This convergence continues when accuracy appears to be stationary. Additional tests conducted under conditions in which the subject was attending to the naming operation prior to the stimulus onset showed no difference in latencies of familiar and unfamiliar letters. In view of these findings, we believe that Fig. 5 provides an indication of the gradual learning of automatic naming associations.

In Fig. 6 is shown a model of three levels of associative learning for this experiment. Any one of the familiar letters may be designated as l_4 and its name by $n(l_4)$; any of the unfamiliar letters may be designated by l_6 and its name by $n(l_6)$. At first the subject may associate the unfamiliar letters with their names by some mnemonic strategy, rule, or image. This state of learning is represented by the lines which connect with the episodic code c_1. Later, as learning progresses, a direct link may be formed. This is indicated by the type of line joining l_5 with $n(l_5)$. Dashed lines, of course, indicate that attention must be focused on the letter to provide the additional activation needed to complete the association and excite the phonological name unit. The solid line joining the familiar letter l_4 with its name $n(l_4)$ represents an automatic association, which allows the stimulus activation of l_4 to then excite $n(l_4)$ while attention is directed elsewhere.

The results shown in Fig. 5 are consistent with this model of automatic

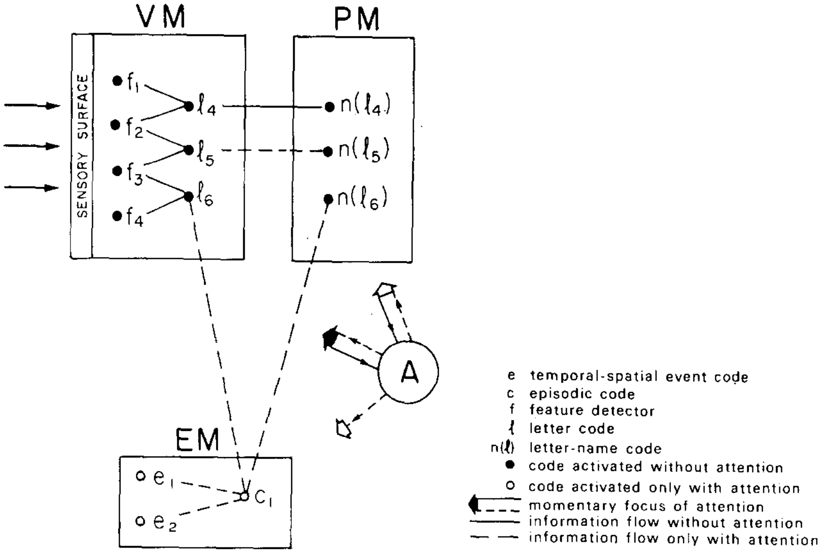

FIG. 6. Representation of three states of associative learning between codes in visual memory (VM), phonological memory (PM), and episodic memory (EM). Attention is momentarily focused on a code in visual memory.

association. However, at the end of 20 days of practice, the college subjects did not name unfamiliar letters as fast as they named the familiar letters, a finding which leads us to conclude that the subjects were still using some degree of attention to make the association. Apparently, it would take a great many more days to bring letter naming of these rather simple letters to the level of automaticity already achieved by the familiar letters. We are tempted to generalize to classroom routines in elementary schools in which letter naming is directly taught and tested only up to the accuracy level. A child may be quite accurate in naming or sounding the letters of the alphabet, but we may not know how much attention it costs him to do it. This kind of information could be helpful in predicting how easily he can manage new learning skills which build on associations he has already learned.

We agree that higher-order reading skills are based more on sounding letters than naming them. Had we instructed the subjects to sound the letters instead of name them, we would regard the expected convergence of latency of the unfamiliar sounds to the latency of the familiar sounds as indicating the gradual development of automaticity in sounding letters. In this case, we would designate the sound of a visual letter code l_5 in Fig. 6 as $p(l_5)$ instead of $n(l_5)$, etc. We assume that the three states of learning to associate a name with a letter would generalize to the case of learning to sound that letter and to sounding spelling patterns and words as well.

Turning to the association of word sounds with word meanings illustrated in Fig. 4, it is possible to perform learning experiments using indicators of automaticity of associating meanings in much the same way as we did for associating names. The only major difference in procedure is that instead of asking the subjects to name a letter, we ask him to press a button if the word is a member of a particular category of meaning (Meyer, 1970).

General model of automaticity in reading. In Fig. 7 all the memory systems relevant to this theory of reading are shown together. We may use this sketch to trace some of the many alternative routes that a visually presented word could take as it proceeds toward its goal of activating meaning codes. A given route is defined here not only in terms of the particular systemic code encountered along the way, but also in terms of whether or not attention adds its activation to any of these codes. A few of the possible optional processing routes may be described as follows:

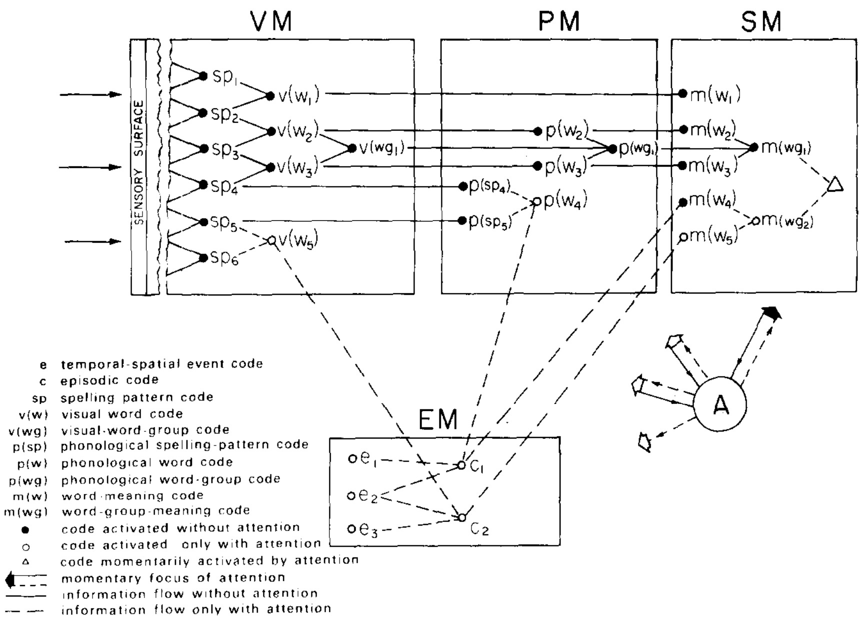

FIG. 7. Representation of some of the many possible ways a visually presented word may be processed into meaning. The four major stages of processing shown here are visual memory (VM), phonological memory (PM), episodic memory (EM), and semantic memory (SM). Attention is momentarily focused on comprehension in SM, involving organization of meaning codes of two word-groups.

Option 1: The graphemic stimulus is automatically coded into a visual word code $v(w_1)$, which automatically activates the meaning code $m(w_1)$. An example is "bear" or "bare" or any very common word which is not processed by Option 2.

Option 2: The graphemic stimulus is automatically coded into a visual word code $v(w_2)$, which automatically activates the phonological code $p(w_2)$. This code then automatically excites the meaning code $m(w_2)$. An example is any very common word which is not processed by Option 1.

Option 3: The graphemic stimulus is automatically coded into the visual word-group code $v(wg_1)$. This code automatically activates the phonological word-group code $p(wg_1)$, which in turn activates automatically the meaning code of the word group $m(wg_1)$. An example might be the words "beef stew" or "après ski."

Option 4: The graphemic stimulus is automatically coded into two spelling patterns sp_4 and sp_5. These units activate the phonological codes $p(sp_4)$ and $p(sp_5)$. These two codes are blended with attention into the phonological word code $p(w_4)$, which activates with attention the episodic code c_1. This code is then activated by attention to excite the meaning code $m(w_4)$. An example might be "skylab," for those who have had few experiences with the word.

Option 5: The graphemic stimulus is coded with attention into the visual word code $v(w_5)$. Attention activates this code to excite the episodic code c_2. When attention is shifted to c_2, it generates the meaning code $m(w_5)$. An example is the name of a character in a Russian novel which is too long to pronounce easily.

An act of comprehension is illustrated in Fig. 7 by the focusing of attention on the organization of two word groups, one of which, $m(wg_1)$, has been automatically grouped, and the other, $m(wg_2)$, has required attention to be grouped. We assume that $m(w_2)$, $m(w_3)$, $m(w_4)$, and $m(w_5)$ can be organized to make sense to the subject only if he can manage to shift his attention activation quickly among these meaning codes to keep them simultaneously active. We are assuming that the process of organizing is promoted by fast scanning at the semantic level in much the same way that fast scanning of feature detectors promotes unitizing of features into new letter patterns at the usual level.

Options 1 and 2 illustrate what many consider the goal of fluent reading: the reader can maintain his attention continuously on the meaning units of semantic memory, while the decoding from visual to semantic systems proceeds automatically. The rest of the examples serve to emphasize that the reader often has the option of several different ways of processing a given word. When he encounters a word he does not understand, his attention may be shifted to the phonological level to read out the sound for attempts at retrieval from episodic memory. At other times he may shift his attention to the visual level and attempt to associate spelling patterns with phonological units, which are then blended into a word which makes contact with meaning. When the decoding and comprehension processes are automatic, reading appears to be "easy." When they require attention to complete their operations, reading seems to be "difficult."

One could say that every time a word code requires attention we are made aware of that aspect of the reading process. For example, when we encounter a word that does not make sense, we may speak it and thereby are momentarily aware of the sound of the words we are reading. Or if the word does not sound right to us, we may examine its spelling patterns, thereby becoming aware of its visual aspects. However, when reading is flowing at its best, for example in reading a mystery novel in which the vocabulary is very familiar, we can go along for many minutes imagining ourselves with the detective walking the streets of London, and apparently we have not given a bit of attention to any of the decoding processes that have been transforming marks on the page into the deeper systems of comprehension.

DEVELOPMENT OF AUTOMATICITY

Throughout this paper we have stressed the importance of automaticity in performance of fluent reading. Now we turn to a consideration of ways to train reading subskills to automatic levels. Unfortunately, very little systematic research has been directed specifically to this advanced stage of learning. Reviews of studies of automatic activity (Keele, 1968; Welford, 1968; Posner & Keele, 1969) deal mostly with automatic motor tasks and, to our knowledge, there are no studies which systematically compare training methods which facilitate the acquisition of automaticity of verbal skills. Therefore, our remarks here will be speculative, although we are currently putting forth efforts in the laboratory to shed light on this problem.

First of all, we would agree with most practitioners involved in skill learning that practice leads to automaticity. For example, recognizing letters of the alphabet apparently becomes automatic by successive exposures (see Fig. 2). Sounding spelling patterns apparently becomes automatic by repetition of the visual and articulatory sequences. Even the meaning of a visual word would seem to achieve automatic retrieval through successive repetitions. Edmond Huey in 1908 emphasized the role of repetitions in the development of automaticity when he wrote, "To perceive an entirely new word or other combination of strokes requires considerable time, close attention and is likely to be imperfectly done, just as when we attempt some new combination of movements, some new trick in the gymnasium, or a new serve at tennis. In either case, repetition progressively frees the mind from attention to details, makes facile the total act, shortens the time, and reduces the extent to which consciousness must concern itself with the process" (Huey, 1908, p. 104).

In the case of perceptual learning, repetitions would seem to provide more than the consolidation of perceptions to the point where they can be run off quite quickly and automatically. Another thing that can happen during these repetitions is that the material can be reorganized into higher-order units even before the lower-order units have achieved a high level of automaticity. For example, when the child reads text in which the same vocabulary is used over and over again, the repetitions will certainly make more automatic the perceptions of each word unit, but if he stays at the word level he will not realize his potential reading speed. If, however, he begins to organize some of the words into short groups or phrases as he reads, then further repetitions can strengthen these units as well as word units. In this way he can break through the upper limit of word-by-word reading and apply the benefits of further repetitions to automatization of larger units. Apparently this sort of higher-order chunking progresses as the child gains more experience in reading. For example, Taylor *et al.* (1960) found that 1st grade children made as many as two fixations per word whereas 12th graders made one fixation for about every two words.

Reorganization into larger units requires attention, according to the model. We do not know specifically how to train a child to organize codes into higher units although some speed-reading methods make claims that sheer pressure for speed forces the person out of the word-by-word reading into larger units. Nevertheless, we feel reasonably sure that considerable application of attention is necessary if the reorganization into higher-order units is to take place. When a person does not pay attention to what he is practicing, he rules out opportunities for forming higher units because he simply processes through codes that are already laid down.

What may be critical in the determination of upper limits of word-group units is the number of word meanings that the subject can comprehend in one chunk in his semantic memory. Units at the semantic level may determine chunk size at the phonological level which, in turn, may influence how attention is distributed over visual codes. Stated more generally, this hypothesis says that the limiting size of the chunk at early levels is influenced by the existing chunk size at deeper levels. If this hypothesis holds up under experimental test, it would imply that the teaching of higher-order units for the reader should progress from deeper levels to sensory levels, rather than the reverse.

We have suggested that during the development of automaticity the person either may attempt to reorganize smaller units (e.g., words) into larger units (e.g., word phrases) or he may simply stay at the word unit level. It stands to reason that he has more confidence in his performance at the lower unit level where he has had the most practice. Whenever he attempts to reorganize word codes into larger units, he may temporarily slow down and perhaps make more errors. Therefore, to encourage chunking, we may have to relax the demand for accuracy. In general, teachers who stress accuracy too strongly may discourage children from developing sophisticated strategies of word recognition (Archwamety & Samuels, 1973). Thus, a child who has performed successfully at one level of processing may be reluctant to leave it and move to higher levels which could eventually improve reading speed.

In the case of association learning, automaticity presumably develops by the sheer temporal contiguity of the two codes. For example, sounding the word "dog" as it is visually presented with no attention to organization of the stimulus and the response may be sufficient for attainment of automaticity. Presumably, proficient readers continue to increase their speed on word-naming tests by sheer practice without special attention to organizing or reorganizing associations.

However, at the initial stages of association, well before automaticity begins to develop, organizational processes are probably involved during a repetition (Mandler, 1967; Tulving, 1962). While it is possible to form an initial associative link directly (rote learning), most likely the subject organizes the stimulus and response together with an event or with a rule and stores this code in episodic memory, as shown in Fig. 3. Later, when the stimulus is presented, attention activates the stimulus code to excite the episodic code. This episodic code now "attracts" attention to activate it further and the code generates its subordinate codes, including the response code. This way of recalling a response requires attention activation and takes a relatively large amount of time. With further repetitions, the stimulus code should begin to short-circuit the episodic code and form a new direct link with the response code. At this point, the stimulus code may require some attention to activate the response code. However, the route through episodic memory remains as an option, and subjects probably use it as a check on the response obtained by the new direct route. With enough practice, of course, activation of the stimulus code excites the response code without attentional assistance.

We expect that the rate of growth of automaticity will depend upon a number of other factors. Two of these, namely distribution of learning and presentation of feedback, have been studied extensively in verbal learning and motor learning experiments. For both motor skill and verbal learning, it has generally been found that distributed practice is better than massed practice, although the optimal interval seems to be a matter of minutes, not days. Massed practice appears to be more favorable when one deals with meaningful material. If we can assume that organizational processing requires massed practice, then we would be inclined to predict that massed practice would be more beneficial for acquiring automatic perceptual processing where organization of codes into larger chunks seems critical. However, automatic associating of sounds or names with these perceptual chunks should involve little if any organization and therefore should profit more from distributed practice.

Since the important growth of automaticity takes place after the subject has achieved accuracy, overt feedback for correct and incorrect responses may be redundant because at this stage of learning the subject knows when he is correct or not (Adams & Bray, 1970). However, there is another type of feedback which may affect the rate of automaticity learning. While learning proceeds toward the automatic level, it might be appropriate to inform the subject of the time it took to execute his response. In fact, the research we have described on acquisition of automaticity routinely informs the subject of his response speed after each trial as well as at the end of a block of trials. Of course, latency feedback for a response to a particular stimulus will not be meaningful by itself, it must be related to some criterion baseline. For example, the time it takes to identify a new word should be compared to the time it takes to identify a word that is already at the automatic level. Thus, the critical metric is the difference between the two latencies. In practice, what we do is present a few old and well-learned patterns along with the new material we wish the subject to learn. At the end of a series of these trials, we show the subject the two latencies. Another way to present feedback is to give it after each response. When his response is faster than the mean on the previous block, he is given a light or sound to indicate a fast response. Aside from the incentive value of knowing how his response speed compares with a criterion, the feedback may influence the way he distributes attention before and immediately after stimulus presentation. This may in turn influence how he organizes the perceptual aspects of reading. As for the purely associative operations, we would suspect that latency feedback would be effective mainly in assuring that the subject continues to respond fast enough to maintain optimal temporal contiguity between stimulus and response codes.

IMPLICATIONS OF THE MODEL FOR RESEARCH IN READING INSTRUCTION

The model which has been presented here may have several helpful features for the researcher concerned with reading. It provides explanatory power by clarifying a number of phenomena which have puzzled educators for some time, and it suggests directions for pedagogical improvement.

One of the current questions in reading is whether it should be considered as a wholistic process or as a cluster of subskills. In support of the subskill view, Guthrie (1973) found that correlations among subskills were high for a group of good readers but low for poor readers, suggesting that they differ in the way they organize component skills. Jeffrey and Samuels (1966) found that children who were taught all of the subskills necessary for decoding words were able to do so without any guidance from a teacher, whereas children who were not taught a particular component were unable to decode.

From the point of view of a mature reader, however, the process appears to be a unitary one. In fact, it is customarily referred to by one label, namely "reading." When a teacher observes a bright child learning to read, he may see the child slowly attaining one skill. However, when the same teacher is confronted with a slow learner, he may observe the child slowly learning many skills. This comes about because the child often must be given extensive training on each of a variety of tasks, such as letter discrimination, letter-sound training, blending, etc. In this manner, a teacher becomes aware of the fact that letter recognition can be considered a skill itself, to be taught like we teach object-naming, for example, naming birds.

The fluent reader has presumably mastered each of the subskills at the automatic level. Even more important, he has made their integration automatic as well. What this implies is that he no longer clearly sees the dividing lines separating these skills under the demands of his day-to-day reading. In effect, this means that he is no longer aware of the component nature of the subskills as he was required to be when he was a beginning reader, learning skills one-by-one. Therefore, if you should ask a typically fluent reader how he perceives his reading process, he is likely to tell you that he views it as a wholistic one.

It seems from our consideration of this model that all readers must go through similar stages of learning to read but do so at different rates. The slower the rate of learning to read, the more the person becomes aware of these component stages. One of the hallmarks of the reader who learned the subskills rapidly is that he was least aware of them at the time, and therefore now has little memory of them as separable subskills. On the basis of this model, therefore, we view reading acquisition as a series of skills, regardless of how it appears to the fluent reader. Pedagogically, we favor the approach which singles out these skills for testing and training and then attempts to sequence them in appropriate ways.

In consideration of each stage, for example, learning to sound letter patterns, it would appear that there are two criteria of achievement: accuracy and automaticity. During the achievement of accuracy, we assume the student should have his attention focused on the task at hand to code the association between the visual letters and their sounds in episodic memory, or to establish direct associations (cf. Fig. 6). Once he has learned letter–sound correspondences, he may or may not be ready to attack the next stage, namely to "blend" these sounds into syllables or words. To ascertain his readiness to move ahead, we must consider a further criterion, namely automaticity. If a good deal of attention is required for him to be accurate in sounding letter patterns, then "blending" will be more difficult to perform owing to the total number of things he must attend to and hold in short-term memory.

In practice, the letter-sound processing need not be fully automatic for him to make progress towards blending, since even the slowest learner has sufficient short-term memory capacity to store a few sounds while he works at blending them. Of course, the less time that his attention must be allocated to the letter-sound processing, the more time he can devote to the blending operation and the faster the progress in learning to blend. We could say that the child who either has a small short-term memory capacity or who has not yet developed the letter-sound skill to the automatic level has too many things to which he must switch his attention in order to carry out the operation of blending. This means that he will forget information crucial to the blending process, and therefore he is more likely to suffer unsuccessful experiences with this task. In short, accuracy is not a sufficient criterion for readiness to advance to skills which build on the subskills at hand. One should take into account the amount of attention required by these subskills as part of the readiness criterion.

COMPREHENSION

We turn now to consider the way the model can be used to clarify some of the comprehension processes and to point to certain pedagogical consequences. In its present simple form, the model does not spell out higher-order linguistic operations such as parsing, predictive processing, and contextual effects on comprehension. If initial tasks of the model are successful, it is hoped that it can be elaborated to represent more complex semantic operations such as these. For present purposes, we find it convenient to separate comprehension from word meaning. By word meaning we refer to the semantic referent of a spoken or written word, morpheme, or groups of words that denote a meaningful unit. By comprehension, on the other hand, we refer to the organization of these word meanings. To do this, the meaning units presumably are scanned one-by-one by attention and organized as a coherent whole. The momentary act of comprehension is represented in Fig. 7 by the focus of attention on the coding of $m(wg_1)$ with $m(wg_2)$. If a subject maintains attention solely on single-meaning codes, this would constitute a rather low form of comprehension, much like viewing characters in a play one-by-one and ignoring their interactions. On the other hand, for high-level comprehension of passages, attention must be directed to organizing these meaning codes, and presumably this is where effort enters into reading just as it does in understanding difficult spoken sentences.

So long as word meanings are automatically processed, the focus of attention remains at the semantic level and does not need to be switched to the visual system for decoding, nor to the phonological level for retrieving the semantic meanings. On the other hand, attention could be focused on the decoding of visual words into their phonological form and spoken aloud without any attention to comprehension. In fact, this has been frequently observed with some beginning readers, and goes by the label of "word calling."

Another phenomenon which the model may clarify is reading for meaning, but without recall for what has just been read. The model indicates that meanings of familiar words and word groups may be activated automatically, leaving attention free to wander to other matters, perhaps to recent personal episodes. If the reader gives little attention to organizing meanings into new codes for storage, it is not surprising that he later finds he cannot recall what he has been reading.

The complexity of the comprehension operation appears to be as enormous as that of thinking in general. When a person is comprehending a sentence, he quite often adds his own associations to the particular organized pattern of meanings. In addition, the ways in which he might organize the meaning units from semantic memory may be influenced by strategies whose programs of operation are themselves stored in semantic memory. We assume that the act of adding material from one's own experiences to what one is reading is represented by switching to other codes in semantic and episodic memory. When this occurs, the item in semantic memory is used as a retrieval cue to access an association or strategy. The finished organizational product presumably is then stored in episodic or semantic memory. When this is successfully done, we say the person can remember what he has read.

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(Accepted November 27, 1973)