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ABSTRACT

A task analysis of the conceptual skills prerequisite to learning to read by a phonics-based method is made in an attempt to distinguish these skills from reading's component skills. The model for task analysis presented by Gagne, in which a cumulative learning of prerequisite conceptual skills is assumed, is used. The analysis deals primarily with Gibson's second and third stages of the reading process: learning to discriminate graphemes and phonemes and learning the rules of grapheme-phoneme correspondence. After the skill descriptions are made, the skills are classified according to type of concept skill (i.e., concepts, rules, and strategies) which are prerequisite to learning the component skills of knowing and using the rules of correspondence. The prerequisite conceptual skills which are task analyzed are (1) multiple discrimination and association, (2) concept of class, (3) information reduction, (4) sequential rules, and (5) logical rules. Related issues which are discussed are (1) inductive and deductive techniques and (2) organized access and use of memory. Prospects for further research are discussed, and a 130-item bibliography is included. (Author/CM)

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CONCEPTUAL SKILLS IN BEGINNING READING

George Marsh

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CONCEPTUAL SKILLS IN BEGINNING READING

George Marsh[1]

I. INTRODUCTION

This paper presents a task analysis of the conceptual skills prerequisite to learning to read by a phonics-based method. An attempt is made to distinguish these skills from reading's component skills.

Basic to this paper is the assumption that analysis of the prerequisite skills is a necessary preliminary to understanding the reading process. This assumption is not universally held. For example, Kolers (in press) states:

> An accurate representation...of any complex skill....cannot be performed inductively by studying the most primitive aspects

[1] I would like to thank Joseph F. Follettie, John Koehler, and Lou Mosberg for their helpful comments and editing of this paper. I would also like to thank Laurie Patton for her patient typing of its many revisions.

> of the reader's performance and working up because there is no principle to guide the induction. We will never come to understand reading if we concentrate our experimentation upon the ability to distinguish geometric forms or the ability to translate graphemes into phonemes or similar tasks.

Levin (1966), on the other hand, argues the value of breaking down the complex skill of reading into its component skills:

> Reading is a skill rather than a body of curricular content.... To think of reading as a complex skill is to borrow an analogy from the research on other skill-learnings in which the total process is analyzed into component parts.

Levin further suggests that the traditional approach to reading research involving comparisons of different methods or different materials in a classroom situation should be superseded by investigation of the specific cognitive skills necessary for learning to read. A similar view is stated by Gibson (1968): "I think that task analysis is essential for a theory of instruction as well as for a theory of learning."

Gibson divides the acquisition of reading skill into four stages: learning to speak, to discriminate graphemes, to decode letters to sound, and to process more than one letter at a time.

Gibson lists learning to speak first because the English writing system is a second order symbol system decoding to speech. Most persons concerned assume that this stage is nearly complete when the child begins reading instruction. In practice this assumption may be unwarranted, as the child may have articulation problems or may have learned to speak in another language or dialect (for example, Spanish and Black English).

Gibson's second stage, learning to discriminate graphemes, may seem trivial to an adult. It is no simple achievement, however, as one can verify by trying to learn the graphemes of an unfamiliar alphabet such as that of Arabic. Because Gibson emphasized visual processes involved in reading, she neglected the related process of discriminating oral units of language. Although the child has been using these units in his speech for several years, Jones (1968) argues that the young listener/speaker does not necessarily analyze speech into components. Thus the child may have to learn to distinguish phonemes if these are used as units in instruction. Bruce (1964), for example, found that young children could not fractionate words, and there is some evidence that very young children do not even perceive spoken words as discrete units (Huttenlocker, 1964).

Gibson's third stage, learning to decode letters to sound, clearly involves more than simple paired-associate tasks, because the sound-letter correspondences in English are not one-to-one. Nevertheless, Venezky (1967) and others have demonstrated that English is appreciably characterized by rule-based spelling-to-sound correspondences. (The description and use of these rules of correspondence is the focus of the Laboratory's Word Attack activity.) In this stage the child learns to perceive the internal structure in the writing system and how it is related to the speech system.

Gibson's fourth stage is learning to process more than one letter at a time. That the skilled reader does not read letter by letter, decoding from left to right, has been evident since Cattell's classic work on word vs. letter recognition, and has been demonstrated in more recent research by Kolers and Katzman(1963) and Newman(1966). As a reader improves he processes larger and larger units, taking advantage of the redundancy in the writing system.

Following Gibson's analysis it is apparent that the units processed change with the stage of learning, progressing from lower to higher. Additional evidence that this is the case in reading acquisition is available: Elkind (1965) reported that tactual discrimination of letters correlated with reading achievement in its early stages but not later; and Calfee and Venezky (unpublished) state that knowledge of the alphabet is highly correlated with reading ability early in first grade, but that this correlation disappears late in first grade because, while almost all children have learned the alphabet, there is still wide variance in the ability to read.

II. TASK ANALYSIS

Task analysis is based upon the model presented by Gagne (1965, 1968). This, model assumes that poor task performance is due to a learning deficit, not a developmental deficit. This assumption differentiates Gagne's model from developmental "ages and stages" models such as Piaget's. For example, if a child could not perform a given task (e.g., the conservation of quantity), Gagne (1968) would assert that this was due to the child's not having learned the prerequisite conceptual skills. Piaget, on the other hand, would assert that the deficit was due to the child's not having yet entered the stage of "concrete operations," which is primarily developmentally or age defined.

The models of Gagne and Piaget are similar in that they both assume a hierarchy of skills. They differ, however, in that Gagne's model is a cumulative learning model, while Piaget's model places less emphasis on the role of learning and experience.

Many unsuccessful attempts have been made to train children in some of the conceptual skills investigated by Piaget (Flavell, 1963, p. 370). Gagne argues that these studies failed not because of developmental limitations of the subject, but because the experimenter tried to train the terminal skill when the children lacked prerequisite skills. The difference between these assumptions is important because they have different practical implications.

The rules of grapheme-phoneme correspondence, for example, might require an understanding of the concept of class inclusion. Since, according to Piaget, this concept does not develop until the stage of concrete operations, it would seem that the only reasonable alternative would be to wait until the child is in the second grade before introducing the correspondence rules. On the other hand, according to Gagne's assumptions, if one knew the prerequisite conceptual skills for this concept, it would be possible to train the child on these, rather than simply wait for maturation.

Gelman (1967) has shown that much of the difficulty that children have with Piaget-type conservation tasks results from the childrens' inability to attend to relevant, and ignore irrelevant, aspects of the problem. In Gelman's experiment, training the child to attend to relevant aspects and ignore irrelevant aspects produced increases in conservation behavior which generalized to other conservation problems.

The rationale underlying the Gagne model is derived primarily from programmed instruction in which the learning sequence is arranged in a logical progression of steps.

Constructing such a logical progression implies the need for a task analysis. The task analysis is initiated by selecting a terminal task and asking what knowledge (e.g., inferred capability of the subject) is required of the student if he is given only instructions to perform the terminal task. The answer to this question identifies a new class of tasks which are simpler and more general than the terminal task. This question is then applied to the simpler tasks to analyze them into their components.

The correctness of such a task analysis, according to Gagne, can be verified by investigating the following hypotheses:

1. If a higher-level task is passed, all related lower level tasks must have been passed.
2. If one or more lower-level tasks have been failed, the related higher-level tasks must be failed.
3. If a higher-level task has been failed, related lower level tasks may have been passed. (This asserts that passing a lower level task is a necessary but not sufficient condition for passing a higher level task.)

If such empirical verification of the task analysis were achieved, it would be possible to initiate a learning program for each individual precisely at the point of his lowest task achievement. Thus the entry skills for some individuals would be en route skills for other individuals.

The procedure devised above resembles closely the "scalogram analysis" first devised by Guttman(1950) for scaling items on attitude tests and applied by several investigators in scaling performances on Piaget-type tasks (e.g., Wohlwill, 1960).

Gagne has developed a number of task analyses for specific tasks such as ordering number series (1962) and conservation of quantity (1968). In addition, Gagne (1965) has provided a general sequence for cumulative learning which is exemplified by Figure 1.

The task analysis proposed here will deal primarily with Gibson's second and third stages of the reading process, that is, learning to discriminate graphemes and phonemes and learning the rules of grapheme-phoneme correspondence. Although the task analysis will describe the component skills of each stage, this is not the primary purpose of the analysis. Description of the component skills is simply the first step toward identifying the types of conceptual skill (i.e., concepts, rules, strategies) which are prerequisite to learning the component skills of knowing and using the rules of correspondence. For this analysis, the terminal task is learning the rules of grapheme-phoneme correspondence developed by Venezky and described by Berdiansky, Cronnell, and Koehler (1969).

Complex rules. In general the correspondence rules appear to fall into the class of what Gagne calls complex rules, because most of the correspondence rules are composed of two or more simpler rules.

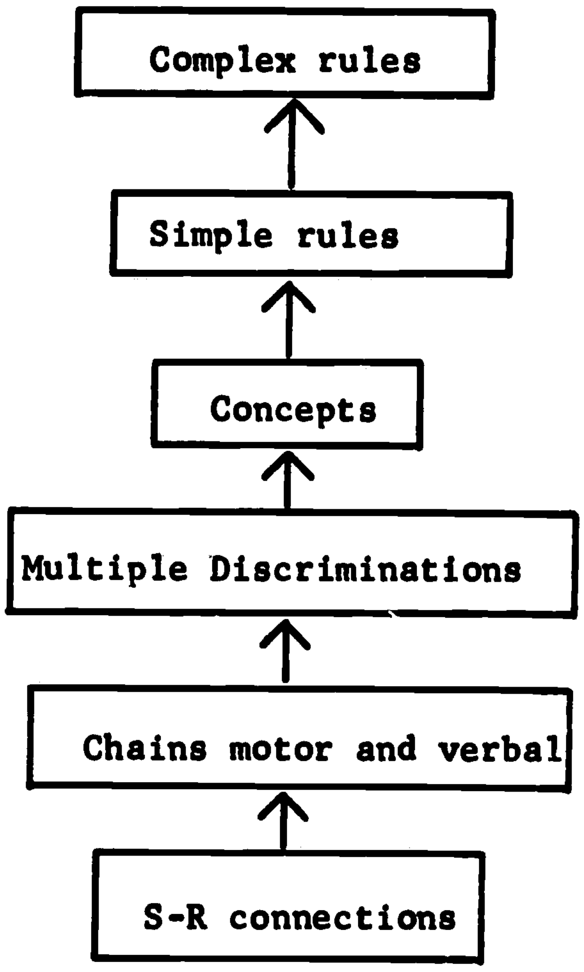
Simple rules. There are two types of simple rules contained in many of the correspondence rules: logical rules and sequential rules.

There are three kinds of logical rule involved: conditional, conjunctive, and disjunctive. Conditional rules occur in all cases in which more than one phoneme is associated with a single grapheme. This includes all the correspondence rules classed by Berdiansky, Cronnell, and Koehler as general vowel rules, almost all those classed as specific vowel rules, and many of those classed as consonant rules (e.g., those dealing with C, G, L, N, and S). Understanding of the conditional rule is a very important skill prerequisite to learning the rules of correspondence.

Conjunctive rules are contained in most of the general vowel rules and also in most of the specific vowel rules. They do not seem to be found in the consonant rules.

Disjunctive rules are also contained in many of the general vowel rules and in many of the specific vowel rules. They also occur in the consonant rules.

Figure 1



Gagné's general sequence for cumulative learning.

Of the three rules concerning logical connectors, the conditional would appear to be of primary importance, followed by the conjunctive, then disjunctive.

Most of the correspondence rules contain a sequential rule component because the pronunciation of a specific grapheme depends not only on the occurrence of other graphemes, but also on the relative and absolute positions of the graphemes in a word.

Some of the sequential dependencies found in the correspondence rules include:

a) is followed by
b) in the final position
c) is immediately followed by
d) is preceded by
e) is preceded by and followed by
f) between
g) not in final position
h) middle

The ability to respond to sequence and position is prerequisite to learning the rules of correspondence.

Concepts. Since the pronunciation of a given grapheme depends upon some but not all of the graphemes present in a word, an understanding of the concept of relevant and irrelevant is involved. The child must be able to restrict attention to the relevant items and positions and to ignore those which are irrelevant. Furthermore, as each grapheme unit is processed in succession, the relevant components of the pattern change.

A second important concept is that of class inclusion. Although a number of rules are specific to particular graphemes, the most generalizable rules (i.e., the general vowel rules) involve an understanding of the concept of "classes." This is true of many of the specific rules as well (e.g., X is pronounced Y when followed by Z and any consonant).

Some of these general classes can be arranged into class inclusion hierarchies. For example, the general class of graphemes and phonemes can be divided into vowels and consonants, which in turn can be divided into long and short vowels, variant and invariant consonants, primary and secondary vowels, silent and sounded items, etc. To do this a child must recognize that a given element can belong to several classes at once.

In addition, many of these classes may be formed according to the concept of exclusion or negation. A pertinent example is the class of vowels and consonants. Although these classes have distinguishing features in phonology, the distinctions may be too subtle for the average speaker.

Hence, the small class of vowels is usually learned by rote while the larger class of consonants is formed by negation. A similar tactic could be used in forming a class of variant and invariant consonants since the class of variant consonants (C, G, L, N, S) is also small. It will be argued later in the paper that an arrangement of items into such hierarchical classes would reduce memory storage requirements and facilitate processing of the graphemes according to the rules of correspondence. Of course, forming such classes depends on learning the basic concept that some items may have a one-to-one correspondence while other items have a one-to-n correspondence.

A second general class-inclusional relationship is found in the combination of graphemes to form larger and larger groups (e.g., geminate consonants, consonant digrams, secondary vowels, syllables, words, phrases, etc.).

It is not clear that the classes of graphemes must be verbally identified by the child or even correspond initially to the traditional class of vowels and consonants. For example, an initial class might be formed between those graphemes (e.g., vowels and consonants) whose correspondences with phonemes are variable vs. those (consonants) which are relatively invariant. However, many of the general rules involve the class of vowels and consonants.

Some of the prerequisite concepts underlying the rules would therefore include:

a) class inclusion
b) variant and invariant
c) negation
d) relevant-irrelevant

The next lowest level, according to the general sequence suggested by Gagne, consists of multiple discriminations of graphemes and phonemes. This process can be broken down into several subprocesses which are discussed in the next section.

The following is an analysis of the conceptual skills involved in the rules of correspondence as sequenced by Desberg and Cronnell (1969).

Table 1. Consonant Rule Conceptual Components

Block(s)	Rule	Conceptual Components
I, II	R, T, N, L, D, P, M, B, F, V, H, K, W, - 10	Multiple grapheme-phoneme associations
III	C-12 & G-12	Conditional Sequential Disjunctive Class inclusion

IV	SH, CK, CH-10, TH-11	Conditional Disjunctive Sequential Syntactic
V	C-11 & G-11	Same as Block III
VI	J, Z, QU, X, Y-10	Same as Block I
VII	NG-10, N20, LE-22	Conditional Disjunctive Sequential
VIII	WH-10, PH-10	Same as Block I
IX	GH-10	Conjunctive Conditional Disjunctive Sequential

Table 2. Primary Vowel Rule Conceptual Components

Block(s)	Rules	Conceptual Components
I	I, A, E, O, U-15	Conditional Conjunctive Sequential
II	E-18 A, E, I, O, U-11	Conditional Conjunctive Sequential
III	E, A, O, I-21	Conditional Conjunctive Disjunctive Sequential Class inclusion
IV	A, E, I, O, U-16	Conditional Conjunctive Sequential Class inclusion
V	A, E, O-17	Syllable Unstressed
VI	A, E, I, O, U 13	Conditional Conjunctive Class inclusion Sequential

VII	A, E, I, O-12 & 14	Conditional Conjunctive Disjunctive Class inclusion Sequential
VIII	O, U-31	No rule components
IX	I-24 & I-22	Conditional Conjunctive Disjunctive Sequential
X	A-23, O-23	Conditional Conjunctive Disjunctive Sequential Class inclusion
XI	E, O-25, Y-19	Conditional Sequential Class inclusion Conjunctive
XII	I, E, O, U-26	Conditional Class inclusion Sequential Syllable
XIII	A, E, I, O-38	Conditional Conjunctive Disjunctive Class inclusion Sequential

Most secondary vowels have invariant pronunciations requiring only that the conjunction of two letters be recognized as a unit and mapped onto the appropriate phoneme. In cases where there are variations in pronunciation of secondary vowels the variants are not predictable from the environment (e.g., OO-11 vs. OO-12, EA-11 vs. EA-31).

III. PREREQUISITE CONCEPTUAL SKILLS

The literature review revealed at least two problems in generalizing research findings to apply to beginning reading. First, much of the relevant research has been done with adults rather than children as subjects. Second, the task materials used in this research are often quite different from the materials involved in beginning reading. The difference in materials may pose less of a problem than the age factor, because the basic hypothesis of this paper is that there are conceptual and information-processing skills which underlie performance regardless what materials are used. In light of the foregoing the literature review serves mainly as a source of hypotheses concerning how various factors may operate in the areas of interest.

MULTIPLE DISCRIMINATION AND ASSOCIATION OF GRAPHEMES AND PHONEMES

The first stage in the task hierarchy consists of learning multiple discriminations between graphemes and phonemes and the association of each grapheme with its appropriate phoneme. The skills involved can be analyzed into at least four sub-skills:

a) Identification and differentiation
b) Production
c) Generalization
d) Abstraction

Identification and differentiation: The child must be able to identify a given grapheme or phoneme and differentiate it from other graphemes and phonemes.

The identification process may be conceived of as matching sensory input to a prototype or template which has been built up through repeated experience and is stored in memory. Differentiation or discrimination, on the other hand, involves responding to dimensions or features which provide contrasts between objects.

A typical task employed in assessing these processes is the matching-to-sample task in which a child is presented with a specific grapheme (or phoneme) and is required to pick out the identical item from a group of similar alternatives. An example of such a task with graphemes can be found in the entry skills test in the SWRL beginning reading program.

Performance on this task confounds the identification and differentiation process since either one or the other or both processes may account for successful performance on the task. An experiment by Pick (1965) involving visual and tactual form provided a transfer test for separating the contributions of these two processes. Pick trained kindergarten children on a matching-to-sample task and then provided a transfer test in which the standard (prototype) was the same as used in original training, but the alternatives differed on dimensions other than those used in training or a task in which the dimensions were the same but the standard was different.

When the forms and their alternatives were presented simultaneously, the results showed that the subjects relied almost entirely on the dimensions rather than on the template in performing the task. When the forms were presented successively, the subjects apparently both constructed templates and learned the distinctive features, since both transfer groups were superior to the control groups. This experiment indicates that the method of processing visual forms may be partly dependent on their mode of presentation.

Pick suggests that building up a schema or template may be necessary when the forms have to be stored in memory, but that the actual function of the schema is to allow comparisons to be made between the dimensions of the stored replica and a present instance.

Gibson (1965) has been concerned with identifying the distinctive features which differentiate English graphemes. A featural approach suggests several possibilities for training children to discriminate graphemes. For example, would discrimination training on isolated distinctive features prior to training on the alphabet, as suggested by Winer & Cromer (1967), produce significant transfer? Should letters which differ on a large number of features be introduced prior to discrimination of letters which differ on only a few features, as suggested by Coleman (1966)?

Coleman (1966) suggests a second approach to improving discriminability between highly confusable letter pairs. He introduced alternation in the graphemes and showed that these alternations significantly increased accuracy in preschoolers' matching-to-sample performance. Unfortunately, he did not test for transfer to the traditional orthography.

The general strategy of providing additional cues can be questioned. The literature on stimulus selection indicates that when several cues for making a discrimination are present, the subjects will tend to focus on the more discriminable cues at the expense of less discriminable or salient cues. Thus, although initial learning may be facilitated, later transfer may be retarded. This result has been obtained in the case of picture context cues in reading (Samuels, 1967) and is possibly applicable using modified orthography (e.g., Initial Teaching Alphabet or diacritical markers) when teaching grapheme-phoneme correspondences.

Although the above discussion concerned the discrimination of graphemes, it is probably also relevant to the problem of discriminating phonemes. The concept of distinctive features was first developed with reference to phonemes (Jackobson & Halle, 1956). It is known that consonant phonemes differ in their disciminability by adults (Miller & Nicely, 1955). A pilot study by Tikofsky and McInish (1968) with two 7-year-olds indicated support for the distinctive features analysis of the errors made on a same-different task.

It seems clear that the ability to identify and differentiate both graphemes and phonemes should precede training to associate them. The literature on paired associate learning suggests that stimulus and response identification and differentiation both logically and empirically precede the associative stage of learning (Underwood, Rundquist, & Schultz, 1959).

This seems generally recognized, since these skills are typically measured in pre-reading entry tests.

Production: The identification process described above does not necessarily involve production of either graphemes or phonemes. The production aspects of beginning reading usually involve only phonemes. The SWRL beginning reading program, for example, requires production of phonemes and words as copies of the production of the instructor. The paired-associate training is unidirectional, that is, the child is required to give an appropriate allophone in response to a printed grapheme. Production tasks in the other direction (i.e., given an allophone, produce the grapheme) are not usually involved in the standard beginning reading program. However, there is little evidence concerning the value of spelling and writing with regard to beginning reading, although programs such as those employed by O. K. Moore would suggest that a systematic exploration of the relationship between writing and reading is in order.

In general, the relationship between identification and production tasks has not been clearly explicated. For example, there is a common assumption among speech therapists that most verbal production (articulation) problems are a result of prior discrimination and identification difficulties. Auditory discrimination of speech sound is therefore prescribed as preliminary remedial training program (cf. Holland & Matthews, 1968). On the other hand, the motor theory of speech perception assumes that production abilities are a prerequisite for identification.

Similar issues arise in connection with the production and discrimination of graphemes. It is obvious that a subject must take account of more attributes of a complex form to produce it than to discriminate it from other forms. Production training then may be beneficial to the identification process if this consists of building up a template of the form and storing it in memory. On the other hand, production training may have negative transfer value for discrimination training because of the required attention to attributes which are irrelevant to the discrimination task. A third hypothesis is that production training will force attention to more features and therefore that the subject is more likely to attend to the relevant feature. Of course, the prediction will depend upon the transfer task. Distinctive features which are irrelevant to discriminating any given two graphemes may be relevant when a different pair is to be discriminated. A study by Williams (1968) indicates that reproduction training was not as facilitating as discrimination training when the task was to discriminate letter-like forms. This was true, however, only when discrimination training involved features presented on the transfer task (cf. the study by Pick discussed previously). Furthermore, the author states that production training may be superior with younger children. This suggests that initially the child needs to build up a recognition template for graphemes, and that successive presentation and production training may facilitate this process. Then the child needs to learn to attend only to criterial features and discard irrelevant features. Simultaneous differentiation training with emphasis on speed of discrimination may be an efficient method for facilitating this process. Studies of transfer from discrimination to production with graphemes seem to be lacking, as do studies combining the effects of these procedures on some transfer task.

Generalization: At some point in the acquisition of reading the child must be able to generalize from a given grapheme to several allophones and from a given allophone to several graphemes. This requirement is evident in the SWRL beginning reading program. The child is introduced to both the upper and lower case forms of the graphemes. Some of the upper and lower case letters (e.g., M, S, C) have enough similarity in shape so that generalization could be expected on the basis of perceptual similarity. Generalization involving other upper-lower case pairs of letters (e.g., A, E, G) probably presume learned equivalence. The child is introduced to both letter names and sounds. In addition, several different letter sounds for the same grapheme are introduced (e.g., a, e, i, t, th) without explication.

A number of questions arise concerning the best way to induce such generalization. Many writers (e.g., Bloomfield, 1942; Fries, 1963) suggest that the child be introduced initially to single letter-sound correspondences. This can be done only by greatly restricting the pool of possible words. This approach has value in helping the child grasp the principle that English is based on an alphabetic system. The problem of course, is that English is not entirely an alphabetic language.

There is some experimental evidence for the position that multiple correspondences should be taught from the start of instruction. A study by Levin and Watson (1963), for example, suggests that learning variable as opposed to constant letter-sound correspondences produces better transfer to a variable list. In a second study, however, Levin and Watson found that a constant list is easier to learn than a variable list, but that the latter produces greater transfer.

A more recent study by Williams (1968) reports that concurrent acquisition of multiple grapheme-phoneme correspondences was better than successive acquisition of the correspondences. The data suggest this effect is not reliable, but at least the concurrent training was not inferior to successive training.

There are related issues. If multiple correspondences are taught, should they be taught in the context of words (e.g., rat, rate) or in isolation? Should generalization training be given only in the context of the rules of correspondence, or can a general "set for diversity" be introduced prior to the learning of the rules?

Abstraction: If a child is going to learn grapheme-phoneme correspondences by induction from whole word, or if he is going to apply knowledge concerning single element pairs to words, then he must be able to abstract (i.e., isolate) graphemes from the context of written words and phonemes from spoken words.

In certain reading readiness tests, for example, the child is presented with several words (usually spoken by the teacher) beginning with the same consonant phoneme, and is required to select from a list the items beginning with the same sound. Venezky et al. point out that this is really a fairly complicated task requiring that the child:

a) distinguish initial, medial, and terminal positions.
b) abstract individual sound.
c) be familiar with the concept of "same."
d) retain the exemplars in memory.
e) compare and contrast speech sounds.

A similar type of same-difference judgment is required on the Wepman Auditory Discrimination Test. This test correlates fairly highly with reading ability and has led some investigators to conclude that difficulty in reading is primarily based on deficiencies in auditory discrimination of phoneme sounds. However, it is clear that rather than just measuring a simply perceptual discrimination, this test measures several complex processes. A recent study by Blank (1968), for example, shows that retarded readers do not have difficulty in perceiving and producing individual words in an imitation task, but that they are inferior on tasks similar to that of the Wepman test. This suggests that the correlation between the test and beginning reading performance is based upon the processing demands of the task rather than simple perceptual mis-identifications.

Training in generalization, abstraction, discrimination, identification, and other information-processing techniques would probably be more beneficial as a remedial treatment for low scores on entry skills tests.

The abstraction training probably initially should be carried out with reference to items in the same modality. Thereafter, training on abstraction of graphemes, given a spoken word, and vice versa, could be given. At a later stage, training on abstraction of higher order units (e.g., spelling patterns) might be initiated. Gibson, Farber and Shepela (1967) have explored a learning set procedure for the abstraction of spelling patterns.

THE CONCEPT OF CLASS

It seems evident that the rules of grapheme-phoneme correspondence require as consituent or prerequisite conceptual skill the concept of class inclusion, since the elements of the system are grouped into classes and these classes can hierarchically arranged. That is, the basic elements--grapheme-phonemes--are classified into larger units such as vowels and consonants, which in turn are formed into secondary vowels, consonant digrams, syllables, morphemes, words and phrases, etc. (although the present analysis stops at the word level).

The logic of class inclusion has been most intensely discussed and investigated by Inhelder and Piaget (1958). They discuss in great detail the logical operations which can be performed upon hierarchically arranged classes. For present purposes, only a few of these operations seem pertinent.

The first of these is the ability to compose the hierarchy by successively combining elementary classes into superordinate classes (e.g., A + A' = B + B' = C etc.) and to use the reverse of these operations to decompose the superordinate classes into subordinate classes (B - A' = A). Underlying this is the ability to see individual items as members of several classes at the same time, which Piaget discusses as an instance of reversible equilibrium (A + A' $\rightleftarrows$ B). According to Inhelder and Piaget (1958), the development of these inclusion relationships is ordered developmentally into seven stages:

1. Resemblance sorting. The child groups together two objects as equivalent on some basis of (perceptual) similarity.
2. Consistence sorting. The child is able to group more than two objects into a single group on the basis of some equivalence criterion.
3. Exhaustive sorting. All the objects which possess the critical attribute are grouped together as being equivalent.
4. Conservation. The child understands that an object retains its class membership even though it undergoes changes in some of its non-criterial attributes (e.g., the child's groupings are no longer heavily influenced by spatial proximities).
5. Multiple-class membership. This stage occurs when the child no longer arranges all classes as mutually exclusive but recognizes that items can be members of more than one class at the same time.
6. Horizontal reclassification. This appears during the production stage of multiple classification, in that the child can actively classify multi-dimensional items in one way, then reclassify them in a different way.
7. Hierarchical reclassification. This is the terminal skill involved in the class inclusion series. As stated previously it consists of the ability to join subclasses to form a supraordinate class and to divide these supraordinate classes into components. Piaget argues that the former occurs prior to the latter in the development of these abilities.

The task analysis hierarchy for the class inclusion relationship therefore yields a hierarchy similar to the task analysis proposed by Gagné and is shown schematically in Figure 2.

Kofsky (1966) constructed a number of tests designed to tap each of the abilities suggested by the stages of Inhelder and Piaget. She found a general ordering of abilities in the group data as suggested by Inhelder and Piaget, but the results of an analysis of the individual data by a scalogram technique were unsatisfactory. Only half of the subjects showed the predicted pattern of successes and failures.

As stated previously, Piaget believed that understanding of class inclusion relations is developmentally controlled and does not reach a complete level until the child reaches the stage of concrete operations (ages 7-11), which includes transitivity, reversibility, associativity, identity, and iteration. In fact, it is one of the most reliable indicators that the stage of concrete operations has been achieved, according to Piaget. If we accept Inhelder and Piaget's analysis of stages as being necessary component skills in the Gagne sense, then the possibility of training these component skills arises.

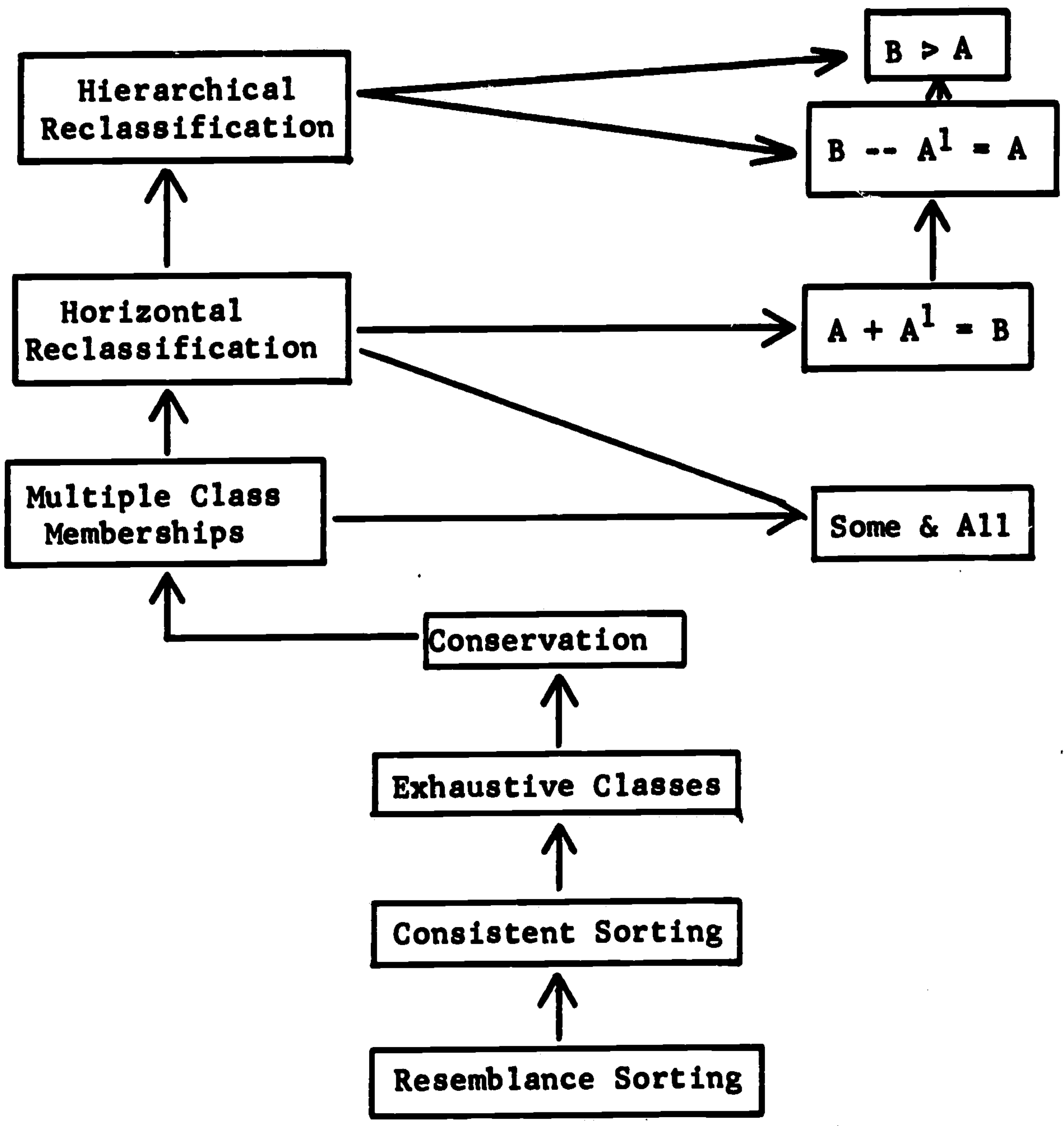
There have been at least two attempts at training children in the class inclusion relationships. Morf (1959) tried three different techniques. Only the third technique, a multiple classification task in which children were trained to consider objects as belonging to two or more classes simultaneously, was even partly successful. However, Kohnstamm (1967), using more or less a shotgun approach which he described as an "intensive learning program in which they were compelled to learn from their faults," was successful in teaching 5-year-old children to solve the inclusion problems.

INFORMATION REDUCTION

It is clear from an analysis of the rules of correspondence that not all the information in a pattern of graphemes is relevant for the decoding of a particular grapheme. In this sense, then, processing the information embodied in a pattern of graphemes resembles a typical concept learning experiment in which there are both relevant and irrelevant cues which may be either redundant or non-redundant. (For example, a vowel is pronounced as its short sound when it is followed by one or two consonants at the end of a word. The consonants following the vowel are relevant and redundant.) Increasing the number of irrelevant variables is equivalent to increasing the amount of information contained in the stimulus patterns. This variable, which Bourne calls complexity, has been found to produce a linear increase in the number of trials to solution (Bugarella & Archer, 1962) in the usual concept learning paradigm. The same result is obtained when the concepts involve temporal order or sequential regularities in stimulus patterns as well as for the usual geometric patterns (Bruner, Wallach, & Galanter, 1959; Barch, 1961). This type of concept learning is probably more relevant to the analysis of regularities in the sequential organization of grapheme patterns.

Bourne and Haygood (1959) varied the number of redundant relevant variables at three levels of complexity (one, three, or five irrelevant variables). Increasing the number of redundant relevant variables

Figure 2


B > A
Hierarchical Reclassification
B -- A1 = A
Horizontal Reclassification
A + A1 = B
Multiple Class Memberships
Some & All
Conservation
Exhaustive Classes
Consistent Sorting
Resemblance Sorting

improved performance at all three levels of complexity but the amount of improvement was much greater with the more complex stimuli than with the least complex pattern. In another experiment the same authors studied the effect of increasing the number of irrelevant redundant variables from two to five. The effect of increasing irrelevant redundant variables was to decrease performance, but the decrease does not appear to be as great as in the condition where the irrelevant variables are uncorrelated.

This set of results is interpreted by Garner (1962) as implying that the subjects are seeking to find structure within the set of stimuli and that redundancy constitutes one type of structure. When the redundancy is contained in patterns which are critical for a response, then facilitation occurs, but when the structure is found in the irrelevant patterns which the subject must learn to ignore, there is a decrement in performance.

Osler and Kofsky (1965) investigated the effects of the number of irrelevant variables in a concept learning task as a function of age. Their results indicated that increasing stimulus complexity has a decremental effect on children aged 4, 6, and 8. The magnitude of the effect was much greater for the 4- and 6-year-old children than for 8-year-olds. At the maximum level of complexity (i.e., two irrelevant dimension) 77% of 8-year-olds solved the problem while only 30 to 40% of the younger children solved it.

It is not clear from Osler and Kofsky's results whether the decrement with increasing stimulus complexity is due to increased memory load or a deficiency in a dimension coding strategy. If the child learns the task as a rote paired-associate task, a one-irrelevant-dimension problem would form a four-item paired associate list, while a two-irrelevant-dimension problem doubles list length. It is possible that older children can merely handle longer lists. On the other hand the older children may recode the stimuli according to dimensions, thus reducing an eight-item list to a three-item list. Experiments in which the number of stimuli and number of dimensions are varied are needed to separate these possibilities.

Another study by Osler and Trautman (1961) indicates that increasing the number of irrelevant cues may be more detrimental to high IQ children than normal IQ children because the higher IQ children generate more competing hypotheses concerning the basis of solution than the normal IQ subjects.

There is also a considerable amount of evidence from perceptual and discrimination tasks that selective attention develops with age and education. According to Harlow (1959) performance on learning set tasks primarily involves learning to ignore irrelevant cues (or eliminate error factors). A review by Reese (1963) of the learning set literature in children shows that there are clear developmental trends in learning set acquisition. Performance increases with both mental and chronological age.

An extensive set of studies on learning set performance of retardates has been carried out by Zeaman and House (1963): their analysis of backward learning curves in this situation indicates that the poor performance of subjects with a lower mental age is not due to differences in instrumental learning per se, but in the pre-criterial attentional stage when performance is stationary. It takes the lower M.A. subject much longer to ignore the irrelevant aspects of the situation and attend to the relevant cues. It is not clear from these experiments whether the critical factor is suppression of response tendencies to the irrelevant cues, or attention to the relevant cues. Restle (1958) has pointed out that there is one relevant cue across problems in a typical learning set experiment (i.e., the reward outcome on the first trial). Thus, a subject who has formed a learning set may have developed a general strategy for ignoring irrelevant cues or he may have learned to pay attention to only the relevant cues.

In the case of the rules of correspondence, both the relevant and irrelevant cues may change from grapheme to grapheme. For example in pronouncing the word CAT the A is relevant for the pronunciation of the C and the T is irrelevant, while the T is relevant for pronunciation of the A and the C is irrelevant. Therefore, it would seem desirable to investigate training procedures which involve both selection of irrelevant attributes and rejection of irrelevant attributes. One type of procedure which seems to accomplish this is the "easy to hard" transfer procedure. House and Zeaman (1967) have demonstrated that by starting out with multi-dimensional objects and proceeding to the more difficult problem with both relevant and irrelevant attributes subjects could perform on problems which they initially failed completely. Many of the Montessori techniques for teaching discriminations between letters and numbers seem to be based upon the principle of "engineering attention" through emphasizing relevant attributes. This is true also for many of the techniques used in remedial reading.

SEQUENTIAL RULES

One of the important cognitive skills required by the rules of correspondence involves the processing of information embodied in the sequential dependencies between graphemes. At the most elementary level, this involves taking account of the position of an item as well as the nature of the item itself. For example, a particular grapheme may be relevant to the pronunciation of a vowel only when it occurs in a particular position in the word (e.g., in the terminal e rule).

The prototype of the SWRL beginning reading program was evolved by Coleman (1966) from a consonant by vowel-consonant matrix in which three or more graphemes are synthesized in order to form simple three- and four-letter words. An empirically based phonics program developed by Silberman (1964) also uses consonant by vowel-consonant matrices. A similar approach is employed by the Stanford CAI group (cf. Rodgers, 1967).

These matrices are conceptually similar to the matrices employed by Esper (1925) in his classic studies on learning miniature linguistic systems. An example of such a matrix is shown below in which the stimuli on one axis are colors, the stimuli on the other axis are forms, and the responses are two nonsense syllables. The first nonsense syllable response is contingent on the color and the second on the shape of the stimulus.

	Shape A	B	C	D
Red				
Green				
Blue				
Yellow				

Esper found that his adult subjects, when given paired associate training on some of the combination of items in the cells of the matrix, could generate the correct responses for cells on which they had received no training. This finding implied that the subjects analyzed the stimuli into component parts and could resynthesize these component items in new and novel combinations. The subjects also had to be able to induce the correct positional ordering of the items in order to generate the correct response to the novel combinations. In general, the learning of these rule-bound combinations proceeded much more rapidly than that for random combinations.

One major empirical question which arises in the context of learning the system embodied in these matrices is whether the learning is faster if the subject first learns the individual items of the rows and columns of the matrix and then synthesizes these items to fill in the cells of the matrix, than when he has to induce the novel combinations from item combinations in other cells. This problem is analogous to the letter-training vs. word-training issue in beginning reading. Although traditional phonics approaches employ individual letters in training, Bloomfield recommends induction of phonics principles from training on whole words. Two studies, both employing unfamiliar graphemes and artificial (nonsense) phonemes, are relevant to this problem. The first study, by Bishop (1964), demonstrated that letter training is superior to word training. In fact, subjects who made this analysis were behaving similarly to the subjects in the Esper experiments, who induced the system from the combination of elements presented. A second study, by Jeffreys and Samuels (1967), using young children as subjects, also demonstrated the superiority of the letter-training technique.

In these studies the relative positions of the items were not preserved from training to transfer as in the Exper experiments, and as they would also have to be in a consonant by vowel-consonant matrix. Therefore, it is difficult to be certain that these findings would apply to the latter situations.

A second empirical question which arises is how the introduction of irregularities into the system affects the acquisition of the system. This question was investigated by Palermo and Eberhardt (1968) in the context of an analogy to learning of morphological rules.

Using the Esper paradigm, Palermo and Eberhardt inserted varying numbers of irregular combinations of items into the 16 matrix-generated pairs. The irregular items were presented two or three times as often as the regular pairs. They found that the more frequently presented irregular pairs were learned fastest but that most of the errors to the irregular pairs were overgeneralizations of the regular pairs. This result is analogous to the findings of Ervin (1964) on the learning of verb inflections in child language acquisition. The general paradigm provided by these investigators may prove valuable in studying the interactions involved in the concurrent acquisition of regular grapheme-phoneme rule correspondences (e.g.. general vowel rules) and the learning of so-called irregular correspondences (i.e., idiosyncratic vowel rules). Although some of the latter may be of low productivity, they involve words which occur with high frequency in the written lexicon.

There seems to be little research on the learning of this type of rule matrices in children outside of the research carried out in the context of beginning reading. The results of some investigators in the latter area (e.g., Silberman, 1964) seem to indicate that transfer from trained to untrained pairs is not very satisfactory.

One study with children which used this type of matrix was carried out by Bruner and Kenny (1966). The items in the matrices were cylinders ordered according to height on one axis and width on the other axis. Bruner and Kenny studied three tasks: replacement of missing items, reproduction of the whole matrix, and transposition of the whole matrix. The tasks varied in difficulty in the above order.

There were clear developmental trends in the ability to perform these tasks. Children of age 7 showed a high percentage correct on all three tasks. As the authors point out, the replacement and reproduction tasks can be performed on the basis of a template matching strategy, while the transposition task requires an understanding of the underlying structure of the matrix.

Many of the younger children could deal with an ordering along a single row or column in which only one aspect of the stimulus pattern changed, but could not deal with the ordering along the diagonal in which the stimuli changed in two dimensions at the same time.

Although no specific training procedures were employed by Bruner and Kennedy, their experiments suggest that giving the child some idea of how the matrix is made up may produce greater transfer than requiring an inductive generalization from some cells of the matrix. In the context of consonant by vowel-consonant matrices, it might be worthwhile to train the child in replacing, reconstruction, and transposing these matrices when presented visually to make explicit the underlying structure of the matrix. Then the grapheme-phoneme correspondences for some cells (e.g., the diagonals) could be taught and the child required to generate the rest of the matrix. This type of training would be useful in showing that letters can be combined with other letters to form words, and that the positions of the letters are critical in forming new combinations (e.g., letters in different positions form different words).

A second area of potential relevance for the learning of sequential dependencies among items is the traditional area of probability learning. In most of these studies, the concern has been only with the subject's ability to learn the average probability with which various outcomes occur. A few experiments, however, have introduced sequential dependencies into the stimulus series itself.

Experiments by Hake and Hyman (1953) and Anderson (1960) indicated that adult subjects can learn conditional probabilities accurately over as little as 50 trials. Offenbach (1965), however, found that while fourth-grade children could learn conditional probabilities between immediately succeeding events, kindergarten children failed to respond to this aspect of the task.

An experiment by Bennett, Fitts, and Noble (1954) showed that adults failed to learn when the response depended on more than just one preceding stimulus. Bogartz (1966) similarly found that children used only the immediately preceding event in obtaining a prediction for the next event sequence. These results are surprising when one considers the ability of adult subjects to use the complex sequential dependencies involved in the natural language (e.g., in the Shannon guessing game technique).

Garner (1962) hypothesizes that the discrepancy between processing sequential dependencies in the natural language and the artificial sequential dependencies is due to the fact that the subjects in these experiments are required to guess initially without any exposure to the patterns, and may be attending to the outcome of their own responses rather than the structure in the stimuli. Sequential dependencies in written materials are presented as spatial patterns rather than time patterns as in these experiments. An experiment by Pufall and Furth (1967) indicated that 4-year-old children could learn simultaneously presented sequences, but failed to learn when these sequences were presented successively.

An extensive series of experiments, mostly unpublished, was carried out by George Miller (1967) and some of his students on learning sequential dependencies in the form of grammatical rules. These rules are in the form of finite state grammars and phrase structure grammars. Miller's description of the research on "Project Grammarama," although fascinating, is generally too anecdotal to be very useful as a basis for understanding the variables involved in learning sequential dependencies.

Smith (1966) demonstrated that when adult subjects are asked to memorize a series of letters constructed according to a simple generative grammar, the intrusion errors in free recall are likely to be consistent with the rules of the grammar. A similar finding was obtained by Segal and Hawkins (1965). The sequential structure (grammar) of the letter pairs used in these experiments is similar to the grammar of the nonsense words used by Braine (1963) in a test of his "contextual generalization" theory for learning the grammatical order of words. According to Braine's theory, the learning of such grammatical dependencies is marked by two phases. Phase I consists of learning the elements of the classes; phase II consists of learning the positions in which the items in the classes may permissibly occur by observation of the simple inter-class contingencies. This learning is hierarchical because the second phase depends upon prior learning of the first phase. According to Braine the process may be in the form of a recursive binary fractionation process. First, larger units (e.g., phases) are segmented and marked for position; later each of these sub-units is segmented again and the items within it assigned to permissible position, etc. Braine has presented evidence that even 4-year-olds when presented with such sequential dependencies do not learn the item pairs by rote, but operate according to the process described in this theory.

The rules of grapheme-phoneme correspondence would seem to require a similar learning of both an item's class and the information concerning positions for the class. Simon and Kotovsky (1963) have described a computer program for simulating the acquisition of concepts for sequential patterns of the type often employed on intelligence tests. The computer program predicted human subjects' performance on these problems with fair accuracy.

LOGICAL RULES

Although much of the traditional work on concept learning involves combinations of attributes according to some of the logical connectors, the primary focus of the experiments is on the learning (or more realistically, the identification) of attributes rather than on the logical rules combining the attributes. In most of these studies the subject is informed of the logical connectors prior to the beginning of the experiment. Bruner, Goodwin, and Austin's (1956) book indicated that disjunctive concepts were more difficult than conjunctive concepts but no direct comparison was made. Hunt and Hovland (1960) found that more subjects chose conjunctive and relational solutions than disjunctive solutions when all three types were possible. Conant and Trabasso (1964) found that disjunctive concepts were more difficult to learn than conjunctive.

The possibility exists that this difference in difficulty is due to the difference in difficulty in using negative instances. Negative instances are more informative in disjunctive than conjunctive problems if the subject uses a "positive focussing strategy." This can be seen in the following truth table:

	Conjunctive	Disjunctive
TT	+	+
TF	-	+
FT	-	+
FF	-	-

Neisser and Weene (1962) expanded the domain of rule learning by identifying 14 possible rules or partitions of patterns in two-dimensional concepts and further showed that these 14 mappings of attributes contain only 10 different rules. These 10 rules fall into five complementary pairs in that any instance which is positive under one member of the pair is a negative instance under the other. The five complementary pairs are shown in Table 1.

These patterns of attributes were divided by Neisser and Weene (1962) into three complexity levels. The first level encompasses the two simplest rules: affirmation and negation. The second level consists of the simple conjunctive and disjunctive rules and their complementary rules (alternative and joint denial). The third level consisting of the conditional and biconditional involve both conjunctive and disjunctive rules, for example (X and Y) and/or (not X and not Y).

This hierarchical arrangement of concept complexity was found by Neisser and Weene (1962) to be reflected in the difficulty that subjects had in learning the problems based on the different rules. Haygood and Bourne (1965) studied intra-rule transfer with four of the rules described by Neisser and Weene (conjunction, disjunction, joint denial, and conditional). They used a learning set procedure in which each subject was given five problems in which the rule remained constant across problems but the attributes changed. The subjects in three main groups were either informed of the rule or the attributes, or neither the rule nor the attributes, prior to beginning the problem sets. The conditional and disjunctive rules were most difficult on the first problem but the differences diminished over the five-problem sets demonstrating intra-rule transfer. However, there was still a residual difference in performance between the rules in the rule learning condition on the fifth problem. The authors interpreted this to mean that there are two different sources of difficulty. The first related to the subject's familiarity with the rules and the second to intrinsic differences in the difficulty of the rules themselves. Evidence from their second experiment indicated that the adult subjects employed in these experiments reduced the M x N matrix of attribute patterns (in their case, a 3 x 3 matrix) into a 2 x 2 matrix which is the

TABLE 1

Basic Rule		Complimentary Rule	
Name	Example	Name	Example
Affirmation	All X are examples	Negation	All not X are examples
Conjunction	All X and Y are examples	Alternative denial	All patterns either not X or Y are examples
Disjunction	All X or Y or both	Joint	All patterns neither X or Y are examples
Conditional	If it is an X it must also be a Y to be an example	Exclusion	All patterns which are X and not Y are examples
Biconditional	X's are examples if and only if they are also Y's	Exclusive disjunction	All X or Y, but not both are examples

functional equivalent of a truth table. According to this "truth table" strategy the subject in a rule learning experiment: a) learns to encode the stimulus patterns into a contingency matrix, then b) learns to assign these stimulus classes to their proper response categories.

A later experiment by Haygood and Kielhbauch (1965) sought to give formal training in this strategy. One group of subjects was given three pretraining problems in which the subjects were required to sort the stimulus patterns into four categories defined by the presence or absence of two named relevant attributes. A control group was not given such training. Then the performance of the two groups was studied in four different rule learning problems. Pretraining on the truth table strategy clearly facilitated the learning of all four rules.

Little developmental data have been published on the rule learning problems described by Bourne and Haygood. King (1966), who trained children aged 6, 9, and 12 and adults on conjunctive and disjunctive rule learning (RL) problems, states that younger children do not respond identically to members of a stimulus class or make proper inference from an FT to a TF case or vice versa. For example, in the conjunctive case both of these are non-exemplars while in the disjunctive case both are exemplars. A TF classification could therefore be used to identify the rule and properly classify an FT instance. Even 12-year-old children did not always make this inference correctly. King suggests three developmental stages. In the first stage children are not able to discover the rule or profit by verbal tutoring. In the second, they can learn to use the rule from verbal instruction, but not by induction. In the last stage a pure induction approach is feasible.

According to the analysis of the logical rules by Neisser and Weene (1962), these rules exhibit a hierarchical structure similar to that discussed elsewhere in this paper (e.g., in connection with rules of class inclusion). The research by Bourne and his colleagues discussed above, however, has studied intra-rule transfer rather than inter-rule transfer. The latter would seem to be of more interest if understanding some of the logical rules is prerequisite for understanding others. The relative difficulty of the rules for various groups of subjects is usually as follows: conjunctive, disjunctive, conditional, and biconditional. This ordering is at least partly consistent with the Neisser and Weene analysis, but difficulty order is equivocal because of possible differing familiarity of rules.

Experiments by D'Amato and Ryan (1967) and Sutherland and Brown (1969) indicate that prior training on an affirmation rule produces positive transfer on a conjunctive rule. A similar study by Lee (1968) investigated the transfer value of three lower level rules (i.e., conjunctive, conditional, and joint denial) on the acquisition of a higher level rule (i.e., the biconditional). Four groups received training on from 0-3 of the lower level rules. The groups' performance on the biconditional was ordered according to the number of lower level concepts experienced. Although

Lee does not report a significance level, it appears that the difference between one and two rules was not significant, but these two groups did differ from both the 0 and 3 rule conditions. However, a second experiment indicated that most of the transfer in the 3 rule condition was due to non-specific transfer in the form of an attribute coding strategy (the same as Bourne's truth table strategy), rather than specific inter-rule transfer. Nevertheless there was an effect of rule training, although smaller than the non-specific effect.

The above research seems to indicate, then, two possible sources of positive transfer--specific inter-rule transfer and non-specific transfer due to an attribute coding strategy. In addition, there are asymmetries between rules that are equally logically complex, such as conjunction and disjunction. Bourne (1968) reported that young children may have particular difficulty with the latter because of difficulty with the negation component. They have difficulty in seeing that two things are alike not because they resemble each other, but because they are not something else. Training on a negation rule may produce positive transfer on disjunctive concepts.

IV. RELATED ISSUES

INDUCTIVE AND DEDUCTIVE TECHNIQUES

Carroll (1964) has pointed out some of the major differences between concept learning as typically studied in laboratory situations and concept learning in the school classroom situation.

1) "The first difference is that concept learning in the school situation often involves genuinely new concepts rather than identification of familiar attributes." The distinction between concept formation and concept identification is relevant here. While accepting this distinction as valid it seems clear that subjects in laboratory situations often do learn new strategies in information processing and perhaps even new rule content.
2) "Concepts learned in school often depend upon a network of related or prerequisite concepts." Some of the conceptual rules (e.g., logical connectors) studied in the laboratory also seem to depend upon the learning of lower-order prerequisite concepts.
3) "Many of the most difficult concepts of school learning are of a relational rather than a conjunctive character. Concept formation experiments have thus far revealed little about the acquisition of relational concepts." Although this statement is true with regard to the older concept learning literature, the more recent studies of learning sequential dependencies are certainly relational in nature.

> 4) "School concepts involve paired-associate memory in addition to concept learning." This is certainly correct with regard to the rules of correspondence, as associations between graphemes and phonemes are a prerequisite to learning the rules of correspondence.
> 5) By far the most critical difference between classroom and laboratory concepts, according to Carroll, is that the former are acquired for the most part deductively, while the latter are usually acquired inductively. Again, however, the distinction is not clear cut. So-called discovery methods, which are inductive methods for teaching content, appear to be gaining in popularity (cf. Keislar, 1968). A pure inductive approach may be a slow and inefficient technique for learning most content, but it may be the only way to learn certain processing skills.

The question of deductive vs. inductive approaches to the learning of the rules of correspondence arises. Venezky, the major formulator of the rules, seems to be of two minds concerning this question. In one paper he and his associates seem to advocate a deductive approach: (Venezky, Calfee & Chapman, undated progress report).

> The failure of subjects to verbalize or employ spelling-to-sound rules does not preclude verbalizing these rules in the teaching of reading. Such verbalization may aid the reader in organizing spelling and sound memories.

However, in another paper (Weir & Venezky, 1968, p. 199) he states:

> The spelling to morphophonemic patterns should not be viewed as rules to teach, as such, but rather as indicators of regularly and irregularly spelled words which have high transfer value and words which have low or negative transfer value for reading other words.

A basic premise of this paper is that verbal presentation of the rules of correspondence would not be a sufficient condition for the acquisition of the rule by a beginning reader. This appears to be the case because the beginning reader lacks many of the prerequisite conceptual skills underlying the rule. On the other hand, the question arises whether a subject with the prerequisite conceptual skills could use such rules if they were presented verbally. There has been little research on questions of this nature.

The most pertinent series of experiments yet published on rule learning was conducted by Crothers and Suppes (1967) in the context of inductive and deductive learning of Russian noun inflections. Their first experiment attempted a purely inductive approach to teaching the rules for Russian noun inflection (which depend on case and gender) to seventh grade children.

The subjects in this inductive approach experiment apparently did not learn anything about these dependencies but instead resorted to a simple "copy the cue noun" strategy. This strategy happened to pay off two-thirds of the time and the subjects were "probability matching," according to the authors. This points to the interesting conclusion that reinforcing a simpler rule may impede acquisition of a more complex rule. This should have implications for the learning of the rules of correspondence.

In a second experiment Crothers and Suppes inserted explicit training on the rules. The rules were presented in the form of conditional statements with multiple choice answers. For example:

> If the sentence contains A, the noun at the end of the sentence ends in the morpheme: X,Y,Z.

A reinforcement was given following each rule presentation. The experiment compared three groups. One group (Rand) had the rule (R) trial and exemplar (E) trials randomly intermixed; in a second group a given R trial was always followed by an immediate exemplar of the rule (Group IE). In the third group (S) the rules were ordered in a progression from simpler to more complex rule constructions. Group S was superior to Group IE which in turn was not significantly superior to Group Rand. The authors' analysis of the data indicated that the R trial did improve performance on the immediate exemplar, but that this effect did not generalize to the other exemplars.

In a third experiment the authors compared two models for sequencing R and E trials. The random trial increment (RTI) model, which is a linear model with no forgetting parameter, predicts that terminal proportions correct should be independent of sequence effects.

A second, long term/short term, model makes predictions for the optimal sequencing of R and E trials. The model ranks these sequences as follows for terminal trial performance (in 4-trial sequence blocks).

(RREE) (RERE) (ERRE + REER) (ERRE) (EERR)

The authors chose three of these sequences for empirical test (RREE, REER, and EERR) in an experiment on learning the rules for conjugating Russian verbs. The terminal proportion of correct responses was ordered according to the predicted order of the R and E sequences.

The theory and experimentation carried out by Crothers and Suppes is unusually valuable from the viewpoint of the present paper. First, it is the only work available on comparing inductive and deductive methods of instruction in rule learning. Second, the rules are sequential dependence rules which are formally similar to many of the rules of correspondence (involving relationships between morphemes rather than graphemes). Third, the authors have worked out some explicit models for optimizing the process of rule learning.

ORGANIZED ACCESS AND USE OF MEMORY

In an undated Progress Report, "Skills required for learning to read," Venezky, Calfee, and Chapman discuss two possible strategies or models for learning to read. These strategies differ with respect to memory requirements.

In the first strategy the child is assumed to store an exact visual replica of each word that he learns and a rote association between the word's pronunciation and the visual replica. In this whole-word template-matching model, the visual form of the word initiates a search for its stored replica which makes available the associated pronunciation pattern. Although this model might be assumed to underlie the whole word technique of teaching reading, it is doubtful that the child can maintain this strategy when the sight word vocabulary is expanded to any considerable degree, because the necessary storage capacity rapidly becomes very large. However, a child taught by whole word technique might maintain this strategy up to the point where the vocabulary requirements become overwhelming. An analogous process has been proposed by McNeill (1966) in the case of language acquisition in which the child first stores utterances in the form of holophrases until the memory requirements become too large and rules for combining words into phrases develop. It seems likely that children by the look and say technique eventually induce spelling-sound correspondences to some extent.

A second strategy mentioned in an unpublished paper by Calfee and Venezky might be called a syllable analogy strategy. The child may segment the word using vowels as the breakpoints and then search for stored representations of syllable-like units until a match is made. The word <u>splint</u> might be broken into <u>spl-int</u>, pronunciations for each segment recovered from more familiar words (splash and hint) and integrated. In this approach, the memory requirements are reduced somewhat since there are fewer syllable-like units than words, but the storage pool of syllable-like units would still have to be relatively large. The cognitive processing requirements are also larger in this strategy.

A third strategy, which might be termed a letter and rule strategy, assumes no match of visual pattern and pronunciation except as a final check. This strategy would involve the smallest memory requirement, since the number of letters and rules is smaller than that for either the syllable or word pool. If a subject mastered the rules of correspondence using this strategy, he could presumably decode any word in the language (or any nonsense words which follow the rules). This strategy demands by far the greatest information-processing capacity.

If we believe the linguists, however, the child already employs an extremely complex set of rules for generating and decoding verbal utterances, so perhaps such a strategy is feasible for the beginning reader.

In this strategy a memory search could be organized according to a hierarchical tree structure similar to that shown in the task analysis.

The processing would be similar to that described as a plan or series of TOTE units by Miller, Galanter, and Pribram (1960).

Take, for example, a subject analyzing the word CAT.

The grapheme C would be analyzed.

Query 1: Vowel or consonant? The list of vowels would be searched and, based on application of negation or exclusion, C would be assigned to the class of consonants.

Query 2: Variant or invariant consonant? The small list of variant consonants is searched and C is located on it, which produces a search for the graphemic environment determining its pronunciation. Since it is followed by A, it is assigned the (K) pronunciation.

The pronunciation of the letter A would be searched in the same manner.

Query 1: Vowel or consonant? Answer: Vowel.

Query 2: Long or short vowel? Answer: Short vowel rule applies.

Similarly the letter T.

Query 1: Vowel or consonant? Answer: Consonant.

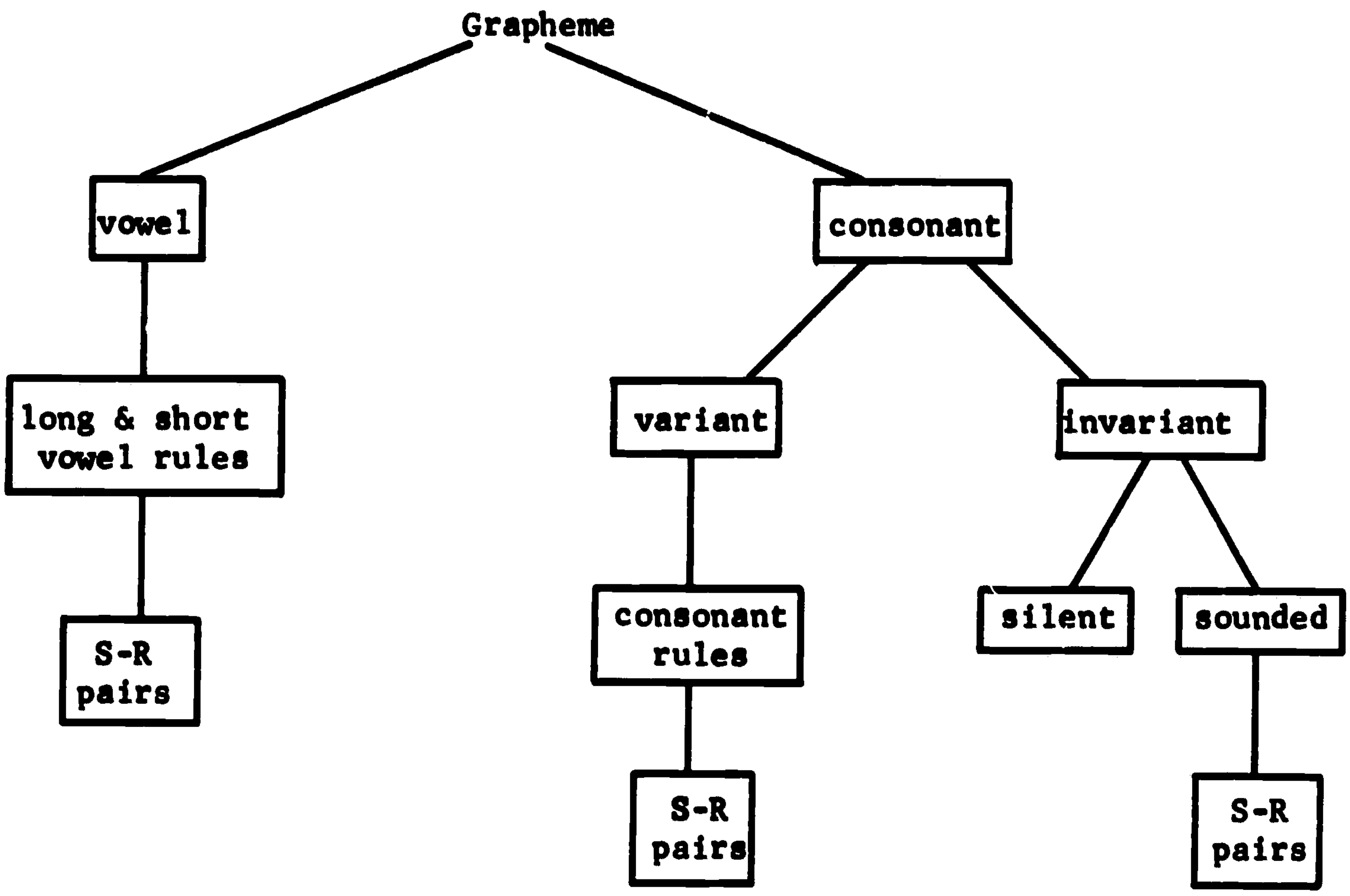
Query 2: Variant or invariant? Answer: Invariant.

This type of search would follow a decision tree which looked something like Figure 3.

The advantages of such hierarchical structures in memory organization have been demonstrated in a number of areas: Mandler (1967, 1968) in a series of papers on organization and memory has found that the number of words recalled in a free recall experiment is a linear increasing function of the number of categories into which the words are organized during training. Mandler suggests that memory for a list of words involves subjective organization in a hierarchical system. In general, he finds that recall involves 5 + 2 categories with 5 + 2 words per category. Bower (1968) has specifically trained subjects in a hierarchical organization of various items. The subjects who received this organization training had recall scores two to three times greater than control subjects given a random presentation condition.

The hierarchical organization is efficient because, as the subject generates items from the top node of the tree, these items generate a retrieval cue for the next lower node, and so on. Such organizational structures are similar to the organizational structures presumed to underlie sentence generation in oral language. Subjects given words organized

Figure 3


Grapheme
vowel
consonant
long & short vowel rules
variant
invariant
S-R pairs
consonant rules
silent
sounded
S-R pairs
S-R pairs

into sentences show about two or three times greater recall than subjects given random strings of the same words.

Hunt's (1962) information processing model of concept learning uses a similar decision tree structure, as does Feigenbaum's (1961) EPAM model for verbal learning, which has been extended to simulate the process used by human beings in learning to read (Feigenbaum, 1963).

Although the particular processing plan or hierarchical organization suggested by the task analysis may or may not be correct, there seems to be little doubt that some systematic approach to analyzing the graphemes would greatly reduce memory load. There has not been much research on training subjects in such processing strategies. Hunt and Feigenbaum programmed their computers to execute such search plans. The question arises as to whether real subjects could be trained in some similar systematic strategies.

Bruner et al. (1956) found that their subjects developed different types of strategies for solving concept problems and that some of these strategies were more successful than others primarily because of reduced memory requirements, but no training procedures were employed. Klausmeier (1964) instructed subjects in a conservative focussing strategy and found that this strategy increased performance in a concept attainment task but Rundquist et al. (1965) failed to find facilitation with such instruction. Byers et al. (1968) showed that this discrepancy was related to the presence of a memory aid in the latter experiment vs. no memory aid in the former. This indicates that the value of training in focussing strategy is due to the reduction in memory requirements.

Several studies have investigated the effect of instructions or hints on diagnostic problem solving. These problems are formally similar to the game of "twenty questions" in that a halving (or constraint seeking) strategy rather than a focussing strategy is maximally efficient for solving the problem.

Young (1968), using adult subjects, found that practice alone was completely ineffective in developing a constraint strategy, while groups which either had the maximally informative response alternative selected for them or were told that these alternatives represented a maximally informative strategy did develop a constraint strategy on transfer (selection) problems.

Mosher and Hornsby (1966) have shown that the use of the constraint strategy increases with developmental level; however, no training procedures were investigated. Niemark (1968) found that providing children with even very non-specific hints (e.g., some moves are better than others) improved the performance of fourth-grade subjects on this type of problem.

It is obvious that such constraint seeking strategies require as a prerequisite skill the ability to organize items in a hierarchical fashion. Thus, two abilities appear necessary--to hierarchically categorize for memory storage and to efficiently search in this hierarchical structure. Whether the former automatically produces the latter is not clear.

There can be no doubt, however, that there is a significant interplay between the organization of the memory store and the plans for retrieving items from memory. These interactions are most clearly spelled out in a recent paper by Norman (1968). He states:

> In a large capacity storage system organization must be determined by the retrieval process. The problem in retrieving information from storage is that neither the exact form or location of the information is known. Two properties of the storage system are important. One is the ability to follow a logical trail of interrelations between the stored items; the other the ability to recognize the valid solutions and reject false ones.

According to Norman's schema each possible input would have representation in storage even if it never occurred. Thus, the subject with a good grasp of the rules of correspondence should be able to recognize nonsense words which conform to the rules as acceptable forms but not actual words and nonsense words which do not conform to the rules as unacceptable forms. There is evidence that adult subjects can make these distinctions and that these differences underlie what is called the "meaningfulness" of nonsense materials long used in verbal learning (e.g., Greenberg & Jenkins, 1964).

V. PROSPECTS FOR RESEARCH

The analysis of conceptual skills in the preceding sections indicates that a few basic conceptual skills underlie all the rules of grapheme-phoneme correspondence. Depending upon the particular instructional approach these skills could be taught as component skills, in the context of learning the rules themselves, or they could be taught as prerequisite skills in the context of simpler tasks. Traditionally, instruction in phonics principles has been postponed until later in the reading process (e.g., the second or third grade). By this time the child has acquired the prerequisite skills through experience either in school or otherwise. It is doubtful that a younger child (e.g., 5 or 6 years old) can acquire all the components of the tasks in the course of learning the rules themselves.

Recent research by Bourne (1969) on learning of logical rules, of the type discussed in Section III, indicated that adults can acquire the necessary subskills (e.g., the truth table strategy) in the context of learning the rules themselves. Seven-year-old children, however, could not learn this strategy when given the terminal task, but were able to transfer the strategy from a simpler sorting task to the rule learning task. Five-year-olds were unable to handle even the simpler sorting task because some of the prerequisite concepts (e.g., negation) were unknown to them. When given training on this subskill, however, they transferred it to the sorting task and then transferred the higher order skills acquired in the sorting task to the terminal rule learning task.

Similarly, studies on transfer between items in a matrix generated list, discussed in Section III, indicated that adults can usually segment the stimulus items and the response units and generate the correct response on an appropriate transfer list without additional training (cf Esper, 1925; Bishop, 1964).

Young children, on the other hand, are generally unable to generalize previously learned responses to novel combinations of stimuli (cf Jeffrey and Samuels, 1967; Silberman, 1964). However, when the children are trained in the component parts of the task, they can usually transfer the previously learned responses to novel stimulus combinations. Such research indicates that the younger the learner the more likely it is that a complex terminal task will have to be broken down into simpler prerequisite sub-tasks. The same conclusion is probably true for the rules of correspondence. If the beginning reader is to be started early on learning a rule and letter strategy for decoding words it is likely that the prerequisite skills will have to be learned prior to the learning of the rules themselves. The potential research areas discussed below represent a best guess at this point of some of the important prerequisite skills.

PHONEMIC SEGMENTATION

It is generally agreed that an important prerequisite skill involved in learning to read is the ability to distinguish the separate sounds in words. For example, Durrell and Murphy (1953) state: "About every child who comes to the clinic with a reading achievement below first grade has a marked inability to discriminate sounds in words."

Similarly, the Soviet educational psychologist Elkonin (1963) has stated:

> In teaching children five and six years old the main fact that we came up against is that they do not know the sounds of language, do not hear and are unable to distinguish the separate sounds within a word. The formation of this action is therefore difficult.

It is probable that underdeveloped phonemic segmentation skills are a major reason why the children in the Jeffrey and Samuels (1967) and Silberman (1964) studies did not show any transfer between matrix generated words. While the studies with adults used bisyllabic materials as responses, the studies with children used short, high-frequency one-syllable words. The difference in results between children and adults therefore might be attributable to the segmentability of the response term rather than ability to perform the other components of the task. The graphemic stimuli on the other hand are not well integrated stimuli for beginning readers and therefore should not provide difficulty in segmentation (cf Marchbanks & Levin, 1965; Samuels & Jeffrey, 1966).

The reason for the child's difficulty in phonemic segmentation is not hard to understand. The beginning reader does not deal with spoken language at the phonemic level. This is clearly the case because to comprehend normal speech at 150 words per minute a listener would have to make 100 phonetic decisions per second. Although the natural unit of processing speech is unknown, Miller (1962) has stated that about one decision per second is a reasonable estimate. This means that the child is processing speech in chunks of two or three words, probably at phrase boundaries. A phonics approach thus requires that the beginning reader attend to speech units (phonemes) which he has had little commerce with since infancy.

Many investigators (cf Dolch & Bloomster, 1937; Bruce, 1964) have concluded that children below a mental age of 7 years are unable to master the task of phonemic segmentation. This conclusion has been used as a basis for delaying the introduction of systematic phonics instruction until late in the reading process (cf Dolch, 1948).

Again, the approach taken in the present paper would suggest that the inability to perform phonemic segmentation tasks may lie in the lack of training in prerequisite skills, rather than in insufficient maturation. Some research suggests that this is the case. Elkonin (1963) was able to train pre-school children in the prerequisite skills necessary for the task primarily by using graphemes as schema or mediators for the sound analysis. This result provides a possible clue as to why the knowledge of letter names prior to learning to read is highly correlated with later reading achievement (cf Chall, 1967, pp. 140-149). The letter names may be used as a tool in the phonemic segmentation task. A similar conclusion is suggested by the fact that children who learn to read at home prior to coming to school often do so as a by-product of printing words (cf Durkin, 1966). Spelling out words, which requires a strategy of segmentation, may have considerable transfer to reading.

The research literature on phonemic segmentation is somewhat sparse and scattered. Phonemic discrimination is a skill prerequisite to phonemic segmentation. A pilot study by Tikofsky and McInish (1968) indicated that consonant discrimination is essentially perfect by 7 years of age although a high error rate to some fricative pairs was obtained.

Calfee, Venezky, and Chapman (1968) obtained much higher error rates with minimal contrast pairs (e.g., mib, mip) in both initial and final position. Overall error rates of approximately 30% were obtained with first graders compared to an error rate of 2% in the Tikofsky and McInish study. A more recent study by Skeel, Calfee, and Venezky (1969) also confirmed the substantial increase in difficulty with the fricatives. All of these studies presented the phonemes in the context of other phonemes and therefore involved a phonemic segmentation task. The phonemic segmentation component, however, was minimal because the child had only to respond same or different (although this is presented in the context of a delayed matching task in the Calfee et al. studies). The terminal skill required for reading is that the child be able to recognize, in an absolute sense, all the sounds of letters including the allophones for vowels in any phonemic environment.

There is evidence that the position of the phoneme is an important variable in phonemic segmentation. Zhurova (1964) found that isolation of final sounds is harder than isolation of initial sounds. Heilman (1961) suggests that recognition of medial vowel sounds will be more difficult than recognition of beginning and ending consonants. It is not clear whether this is due to the medial position or represents some intrinsic difference between vowels and consonants.

There may be an important difference between phonemic segmentation in real and nonsense words. Luria and others have suggested that, to the young child, the sound of a word is strongly bound to its semantic referent. This implies that segmentation should be easier in the context of nonsense or unfamiliar words. McNeil and Stone (1965) reported some evidence to support this hypothesis. They also found that phonemic segmentation abilities developed with nonsense words transferred to real words. This is in contrast to discrimination tasks in which phonemes are discriminated better in words than in nonsense syllables (cf Calfee et al. 1968). These apparently contradictory findings probably reflect differing task requirements. The role of subject vocalization is also in need of exploration. Holland and Matthews (1968) reported that subjects who spontaneously vocalized during a speech discrimination task seemed to perform better than those who did not vocalize. The information provided by the literature on phonemic segmentation should provide a sufficient starting point for a series of investigations of the variables affecting ability to learn this prerequisite skill. According to a literature review by Chall (1967), the ability to hear the sounds in words is one of the best predictors of success in beginning reading. There is some reason to believe that it should be developed prior to or concurrently with learning of letter names of letter sounds. The learning of the alphabet or letter sounds in isolation is a difficult task for the young child. If the child does not recognize the responses involved in the task as already existing in his repertoire, they represent meaningless abstractions. If the letter sounds can be recognized as the phonemic constituents of words, then the child can assign these "abstract" sounds to the same memory register as the phonemes already stored in memory.

DISCRIMINATION AND ABSTRACTION OF GRAPHEMES

The discrimination and abstraction of graphemes from the visual word is a process analogous to the discrimination and abstraction of phonemes from an auditory word environment discussed above. Again, discrimination of graphemes is a prerequisite skill for the abstraction of graphemes. As is the case for phonemes, the literature on grapheme discrimination is somewhat conflicting. Although letter-pairs clearly differ in similarity (cf Dunn-Rankin, 1968) these differences do not seem to produce large difficulties in visual discrimination of graphemes. Gibson, Osser, Schiff, and Smith (1963) found that, given normal viewing conditions, nursery school children make few errors in discriminating capital letters in a matching to sample task.

As is the case with phonemes (some fricative pairs) there is a small group of lower case letters (p, b, q, d, n, u) whose discriminability is difficult for the beginning reader (Davidson, 1935; Karraker, 1968). These letters have only one distinctive feature--spatial orientation, and this feature children have learned to ignore in object constancy.

A number of experiments on tachistoscopic word recognition by the Gibson group at Cornell (Gibson, Pick, Osser & Hammond, 1962) have indicated that graphemic stimuli are processed in terms of higher order units which Gibson calls "grapheme-phoneme correspondences." These essentially refer to English spelling patterns such as the positionally constrained consonant and vowel clusters.

Gibson's initial hypothesis was that pseudo-words conforming to English spelling patterns were perceived more readily because they were pronounceable (i.e., mapped more or less invariantly to sound). A developmental study by Gibson, Osser, and Pick (1963) found that pronounceable trigrams were perceived at lower thresholds even by first- and third-grade children. However, more recent investigations by Gibson, Schurcliff, and Yonas (1966) and by Thomas (1968) indicate that the structure or redundancy provided by the visual spelling patterns themselves may be the important factor.

An important area of investigation, then, is to find how the child learns to induce the structure inherent in the graphemic stimuli from multiple instances. Responding to these spelling patterns involves the isolation of graphemes in a word environment, paying attention to a conjunction of graphemes, and paying attention to both relative and absolute position. It is clear that these skills are prototypes of the conceptual skills involved in the more complicated rules of correspondence.

Gibson, Farber, and Shepela (1967) attempted to train kindergarten children on the abstraction of spelling patterns by means of a learning set procedure. All but one of their subjects failed to show any improvement over a period of extensive training. This failure may have occurred because training on this complex terminal task was not preceded by practice on tasks to improve the prerequisite skills.

The literature on concept learning suggests a rationale for the sequencing of the component skills involved in the abstraction of spelling patterns. The terminal task can be conceived as consisting of two dimensions, a) an alphabetic dimension, and b) the position dimension. The first stage of training would involve training of a simple presence-absence concept on the alphabetic dimension. The second stage would involve an intra-dimensional shift to a conjunction of two graphemes. D'Amato and Ryan (1967) have demonstrated positive transfer from a simple-presence absence concept to a conjunctive concept. The third stage would involve an intra dimensional shift from the alphabetic dimension to a conjunction of alphabet and position as relevant variables. The fourth stage would be the terminal task of a conjunction of graphemes and positions relevant. Such a training sequence would allow identification of the areas of difficulty which the beginning reader may have in terms of:

a) isolating graphemes from a word environment
b) paying attention to position as a relevant dimension
c) paying attention to both specific graphemes and their positions

The research can be designed to assess both specific and general transfer. For example, does the ability to respond to a specific spelling pattern in one set of environments transfer to other environments? More importantly, does the child learn general processing skills which will transfer to the abstraction of novel spelling patterns? The same questions are relevant to the research on phonemic segmentation discussed previously.

A second stage of the research would involve investigation of the interaction between the visual and auditory modes. It was previously suggested that the grapheme may serve as a mediator for phonemic abstraction (Elkonin, 1963). In a similar fashion the invariant mapping of visual patterns to sound may facilitate their integration as visual units. As described above, the tasks on the auditory and visual sides are somewhat opposite. The child must learn to segment a well-integrated auditory response and to synthesize poorly integrated visual stimuli. The contributions of the cross-modal invariances to these processes would be a logical step in the research.

ORGANIZATION AND MEMORY

An important question touched on in Section IV relates to the question of how to facilitate the organization of letter-sound correspondences and rules to improve their retrieval from memory.

One possibility would be to attempt to group into one class all the graphemes and grapheme clusters that map into the same phoneme. Since many identical graphemes map onto different phonemes, some type of external coding scheme must be used. Such a system employing color codes is employed in the "words in color" approach of Gattegno (1966). The problem with such external codes is that the groupings are functionally useless when the external code is removed. An alternative approach is to group into one class all phonemes that map onto a single grapheme or grapheme cluster. Such an approach is embodied in the approach taken by Williams (1968) on concurrent acquisition of multiple grapheme-phoneme associations. Such a strategy may be useful in that the possible phonemes may be ordered according to their probability of occurrence, and that alternative pronounciation may be retrieved from such a frequency hierarchy until a match is made with a known acoustic representation.

A more reasonable strategy probably would be to always present the alternative phonemic representations in their appropriate word environment so that the conditional cues may be stored in the same location with the appropriate pronounciation. Empirical research, however, is needed to sort out these alternative modes of presenting materials. In the SWRL beginning reading program, for example, the child is taught both letter names and letter sounds, thus mapping two sounds onto a single grapheme. The rationale for learning letter names is not explicated, but since the letter names for vowels are the same as the long vowel sounds, the previously learned classification may be useful when the time comes to process long and short vowels in a word environment. Many of the rule groupings by similar environments suggested by Desberg and Cronnell (1969) depend upon the child having functional conceptual categories for long and short vowels if any specific transfer is to be expected across vowels.

An important area of potential investigation is the use of redundant cues such as modified orthography, diacritical markers, or color cues (to name a few) to provide a basis for classification of graphemes. Although there is considerable literature comparing reading systems using such devices with conventional systems, as is typical of much educational research there are too many confounded variables to draw any conclusions. For example, in the studies comparing the initial teaching alphabet with conventional systems, modified orthography, amount of phonics, and amount of writing were all confounded (cf Chall, 1967).

Restricted experimental studies of such external memory aids may throw more light on their value. There is a considerable research literature (cf Trabasso & Bower, 1968) which suggests subjects pay attention to highly salient relevant redundant cues at the expense of less salient relevant cues. On the other hand by making a gradual transition (fading) from the more salient cue to a less salient one it may be possible to effect economy in learning time.

Another major variable which affects the organization of materials is the input sequence. A general question which is raised continuously in the paper by Desberg and Cronnell concerns the issue of concurrent or successive input sequences. An example is the differential responses which must be made to patterns of letters and the component letters which make up those patterns (e.g., the consonant digrams and secondary vowels). Studies by Estes and Hopkins (1961) and Friedman (1966) have shown that there may be considerable interference in learning differential responses to the patterns and components but that adults generally develop a strategy appropriate to discriminating such pairs which will transfer to other novel combinations. The strategy probably consists of assigning the components and the patterns to different memory storage registers. An analogous process is seen in recoding digits. A subject will often show associative interference between the patterns 19 and 91 if these are stored as individual elements. However, when they are recoded as nineteen and ninety-one, little associative interference occurs in retrieving them from memory. Presumably an analogous process occurs which allows minimization of interference in processing single consonants, and vowels and consonant digraphs and secondary vowels. It would be desirable to investigate procedures for facilitating such recoding or chunking. In the experimental literature the components and patterns are usually presented concurrently during training. This is in contrast to the usually recommended successive input of single consonants and consonant digraphs or vowels and secondary vowels. An investigation of the sequencing variable would be a useful starting point for reducing uncertainty regarding the optimal procedure to follow. Of course the same question arises with regard to many other rule components (variant sound of consonants, long and short vowel, etc.).

In the instructional sequence it may be necessary to introduce a small class of words as exceptions to be learned as sight words. Again, to minimize interference these words must be stored in memory separately from regularly pronounced words. This will be easier if these words have some discriminable characteristics or some list structure which differentiates them from the regular words already known.

In general the materials should be organized so that the beginning reader can have some systematic plan for decoding unfamiliar words. Such a plan can operate efficiently only if graphemes which have similar functional rule characteristics are grouped together in the same storage locations. Such groupings should maximize the positive transfer potentially available in the general vowel rules and consonant rules with similar environments.

In the present SWRL first-year reading program, only one pronounciation of each grapheme is introduced, thus minimizing any grouping of graphemes in memory according to their functional characteristics. Although the short vowel rules occur, they are not taught as rules because no negative exemplars occur. Whether this is the optimal procedure for maximizing positive transfer in the situation when the grapheme-phoneme relationships are variable deserves empirical investigation.

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