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COLLECTING A DATA BASE FOR AN EDUCATIONAL TECHNOLOGY. 1, EVOLVING A PSYCHOLINGUISTIC READING PROGRAM.

BY- COLEMAN, E.B.

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DESCRIPTORS- *PSYCHOLINGUISTICS, *READING RESEARCH, *MATERIAL DEVELOPMENT, *BEGINNING READING, BASIC READING, READING SKILLS, SEQUENTIAL LEARNING, LEARNING, PHONICS, LEARNING THEORIES, STIMULUS BEHAVIOR, SOUTHWEST REGIONAL LABORATORY,

SOON IT WILL BE POSSIBLE TO REDUCE TO A TECHNOLOGY THE CONSTRUCTION OF MATERIALS FOR THE PRINTED COMMUNICATION SKILL IN FIRST GRADE. THIS TECHNOLOGY REQUIRES A DATA BASE, A HUGE MATRIX OF S-R FUNCTIONS THAT PLOT THE EFFECT OF A STIMULUS-DIMENSION UPON A READING RESPONSE. A CONSIDERABLE PORTION OF THE DATA BASE CAN BE PROVIDED BY REPLICATING PREVIOUS EXPERIMENTS WITH RELEVANT LEARNER POPULATIONS AND RELEVANT LANGUAGE POPULATIONS. THIS DATA BASE WOULD CALIBRATE LINGUISTIC UNITS AS TO LEARNABILITY. AN EDUCATION ENGINEER COULD ORDER THE LOW-ORDER TASKS OF READING INTO A SEQUENCE THAT WOULD FACILITATE THE INDUCTION OF MORE GENERAL CONCEPTS, SUCH AS THOSE OF PHONICS AND SPELLING. TO COLLECT A DATA BASE OF THIS MAGNITUDE, EDUCATION AND PSYCHOLOGY MUST INCREASE THE EFFICIENCY OF THEIR RESEARCH TECHNIQUES. EDUCATION MUST PRODUCE CHEAPER AND MORE EFFICIENT DATA COLLECTORS. A COMPLEMENTARY STRATEGY FOR PRODUCING MATERIALS WOULD BE TO REFINE A PROTOTYPE THROUGH A SELF-CORRECTING CYCLE OF TEST-REFINE-TEST-REFINE. A RAPIDLY EVOLVING PROTOTYPE CALLED THE PSYCHOLINGUISTIC READING PROGRAM IS DESCRIBED. TABLES AND FIGURES ARE INCLUDED. (AUTHOR)

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COLLECTING A DATA BASE FOR AN EDUCATIONAL TECHNOLOGY:
I. EVOLVING A PSYCHOLINGUISTIC READING PROGRAM

E.B. Coleman

Southwest Regional Laboratory.

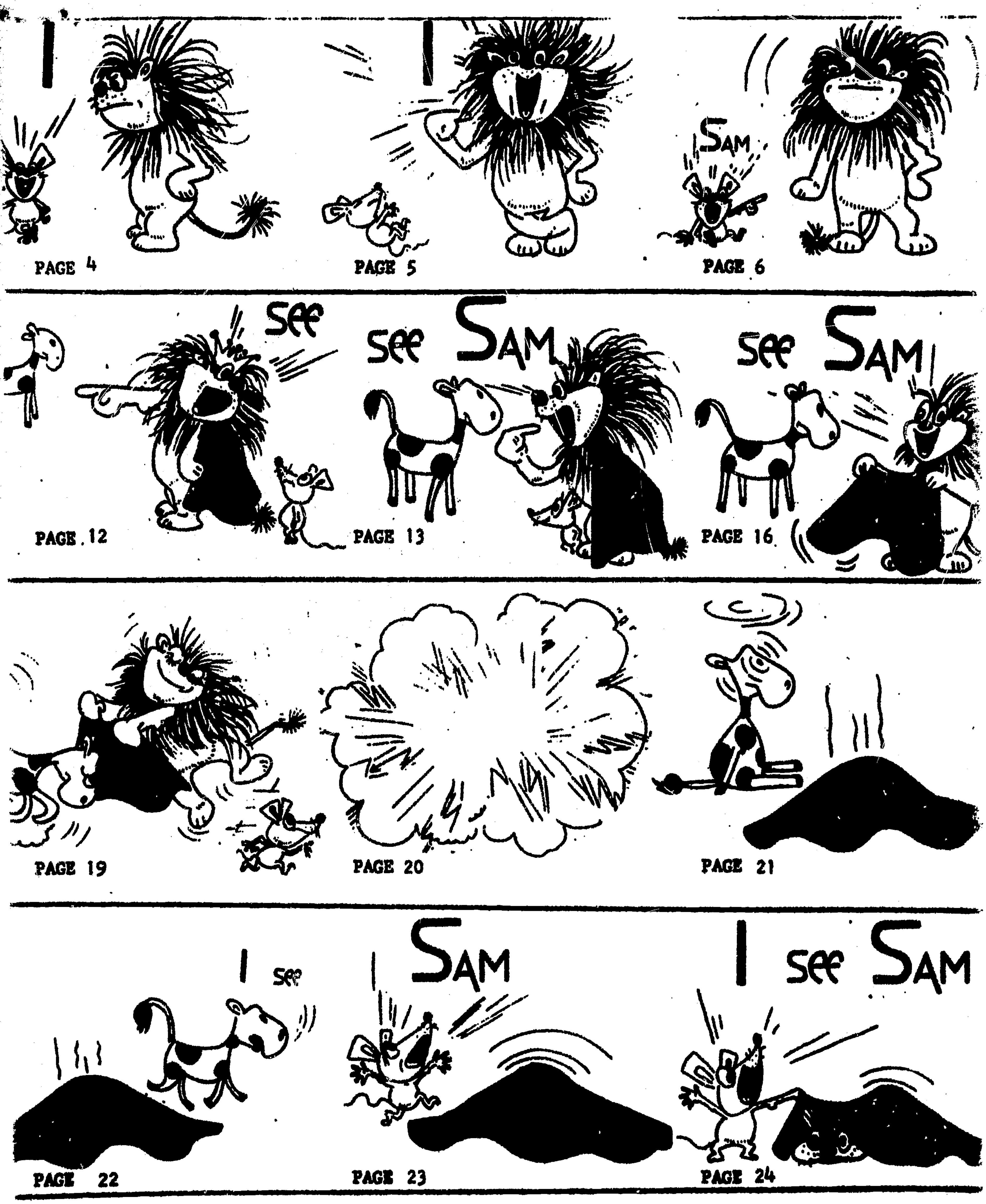

FIG. 1. EXCERPTS FROM A BOOK THAT MOST FIVE-YEAR-OLDS CAN LEARN TO READ IN A 20 MINUTE LESSON. IN ITS LAST TEST, OVER 75% OF A CLASS OF KINDERGARTENERS LEARNED TO READ IT AFTER A SINGLE LESSON.

One thesis of this paper is that we can make significant improvements in the teaching capacity of elementary reading material simply by exploiting the psycholinguistic data available at present. By manipulating characteristics that affect teaching efficiency, we can construct books so simple and efficient that most five-year-olds can be given the thrill of reading real books in a single twenty minute lesson--books so simple that our five-year-olds can be taught to read them at home by television--books so efficient that they simultaneously teach reading, spelling, phonics, and printing.

Figure 1 shows excerpts from a book that most five-year-olds can learn to read in one twenty minute lesson. By relying heavily on cartoons, the complete book tells an entertaining story using only three words, "I, Sam, see."

The book and the lesson are in a continuous cycle of testing and refinement. We have tested them--including earlier versions--in three kindergartens. In the last test, over 75% of the children in a kindergarten class were able to take the book home and read it after a single lesson. The next day, in an individually administered test on a new book using the same three words, 27% read the new book perfectly. Only 18% missed more than half the words in the new book.

The usual preprimers are so difficult that they require a considerable amount of maturation and pre-reading training. By controlling characteristics that affect learnability, it is possible to construct a long series of pre-preprimers beginning with a book simple enough to be read and enjoyed immediately (see Fig. 2). The series begins at such a simple level and increases in difficulty so gradually that a preschooler can be taught all the concepts of reading readiness--and much, much more--by actually reading entertaining little books. Thus, even with the present data base, it is possible to redefine and extend the notion of reading readiness.

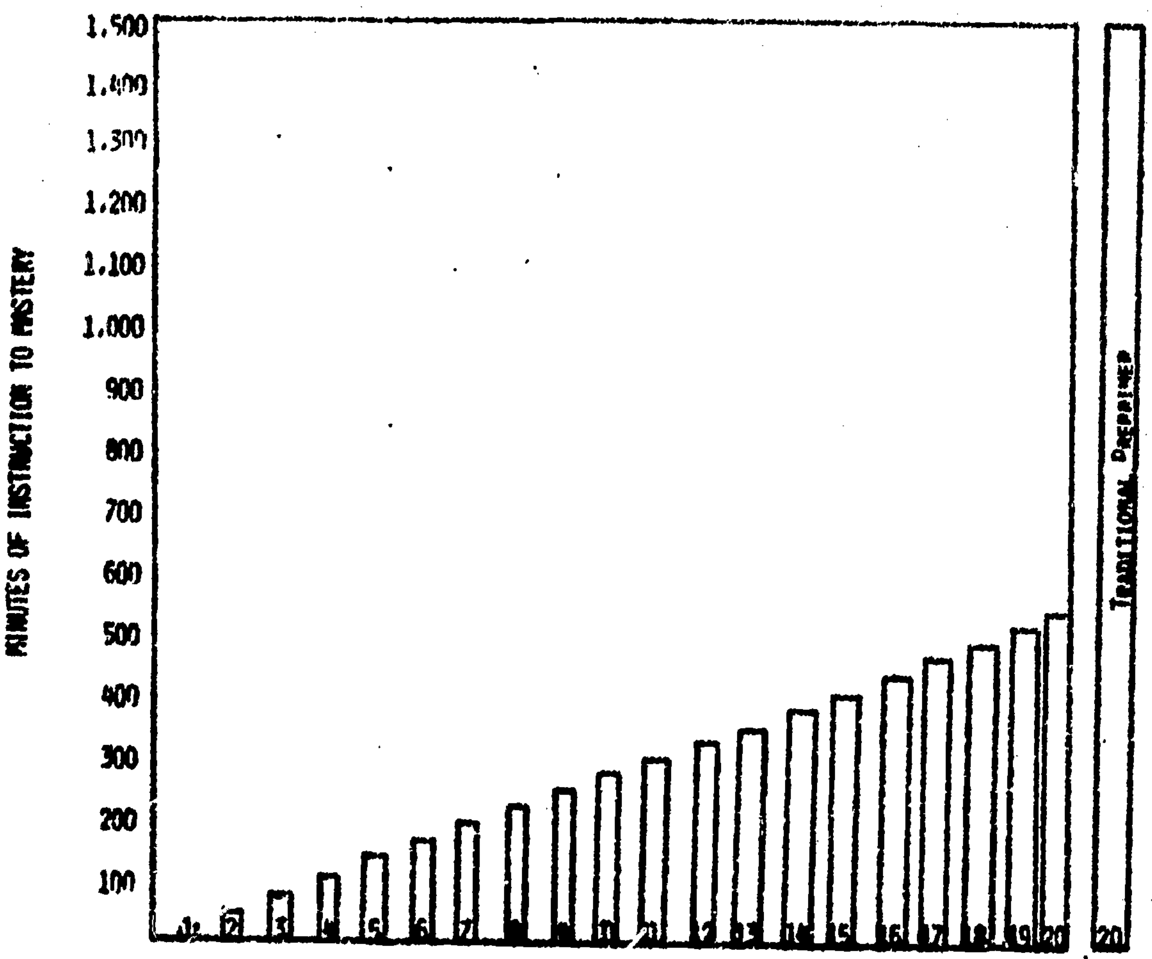

FIG. 2. TRADITIONAL PREPRIMERS ARE SO DIFFICULT THAT THEY REQUIRE A CONSIDERABLE AMOUNT OF PRE-READING TRAINING, BUT BY CONTROLLING CHARACTERISTICS THAT AFFECT LEARNABILITY, IT IS POSSIBLE TO CONSTRUCT A LONG SERIES OF PRE-PREPRIMERS BEGINNING WITH A BOOK SIMPLE ENOUGH TO BE READ IMMEDIATELY.

DETAILS OF A PROTOTYPE READING PROGRAM

The major purpose of this paper is not to give a detailed description of the reading program possible with the present psycholinguistic data base; the major purpose is to advocate multiplying the size of that data base a hundred times over. However, one strategy for producing materials is by refining a prototype through a self-correcting cycle of test-refine-test-refine. This research strategy can be followed concurrently as we collect an adequate data base. Thus, a secondary purpose of this paper is to describe such an evolving prototype. Let us call it a psycholinguistic reading program. It is worthwhile to digress momentarily and describe a few of its details since they are specific examples of more general matters to be discussed later.

	ee	I	A	i	e	u
		I	A			
s	see		SAM sat sad	sit sis	set	SUN US
m	MEE meet		AM MA MAN MAD MATT	MISS	MESS met	
s	sees			is		
t			at	it		
n	need		ANN NAN	IN		NUT
th	thee		that	this	then them	
d			AND	did	ed	
w	wee			will with win	wet well	WUS
f	feel feet		FAN fat	fill fish if	fell	fuss FUN
l				ill	let	
sh	shee sheet					shut
r			ran rat			run
h			hat			

FIG. 3. A VOWEL-BY-CONSONANT CHART SHOWING THE FIRST 64 WORDS INTRODUCED IN THE PROGRAM. THE WORDS WERE SELECTED TO PERMIT THE SIMULTANEOUS USE OF ALL READING SYSTEMS AND TO FACILITATE THE INDUCTION OF THE CONCEPTS UNDERLYING SPELLING AND PHONICS.

Figure 3 is a vowel-by-consonant chart that shows the first 64 words and the first letter-sounds introduced in our program. Note that the words occur very frequently in English; they were selected because their response availability is high enough to make them easy to teach by look-and-say, whole-word memorization. Note also, however, that they are regularly spelled; they were selected to permit a spelling or phonics approach. Note that almost all of them are words found in linguistic readers so they permit that approach. Note also, however, that they are supplemented by a number of function words--some misspelled in a transitional alphabet--so they permit the idiomatic sentence structure of the Initial Teaching Alphabet (but with only a tiny fraction of its misspellings). More generally, the words are selected to permit the simultaneous use of all reading systems and to facilitate the induction of the concepts underlying spelling and phonics.

In Fig. 3, the vowels and consonants are arranged in the sequence in which they are introduced. Note that the first sounds are continuants. More important, they are continuant sounds that have meaning in English. The component sounds of the first words can play a meaningful role in the first stories. Figure 4 shows one of the many techniques this program can use for teaching spelling and phonics, techniques that would not be available if the first words were "come," or "look," or "go."

from Sis and the Three Bears
(Southwest Regional Laboratory)

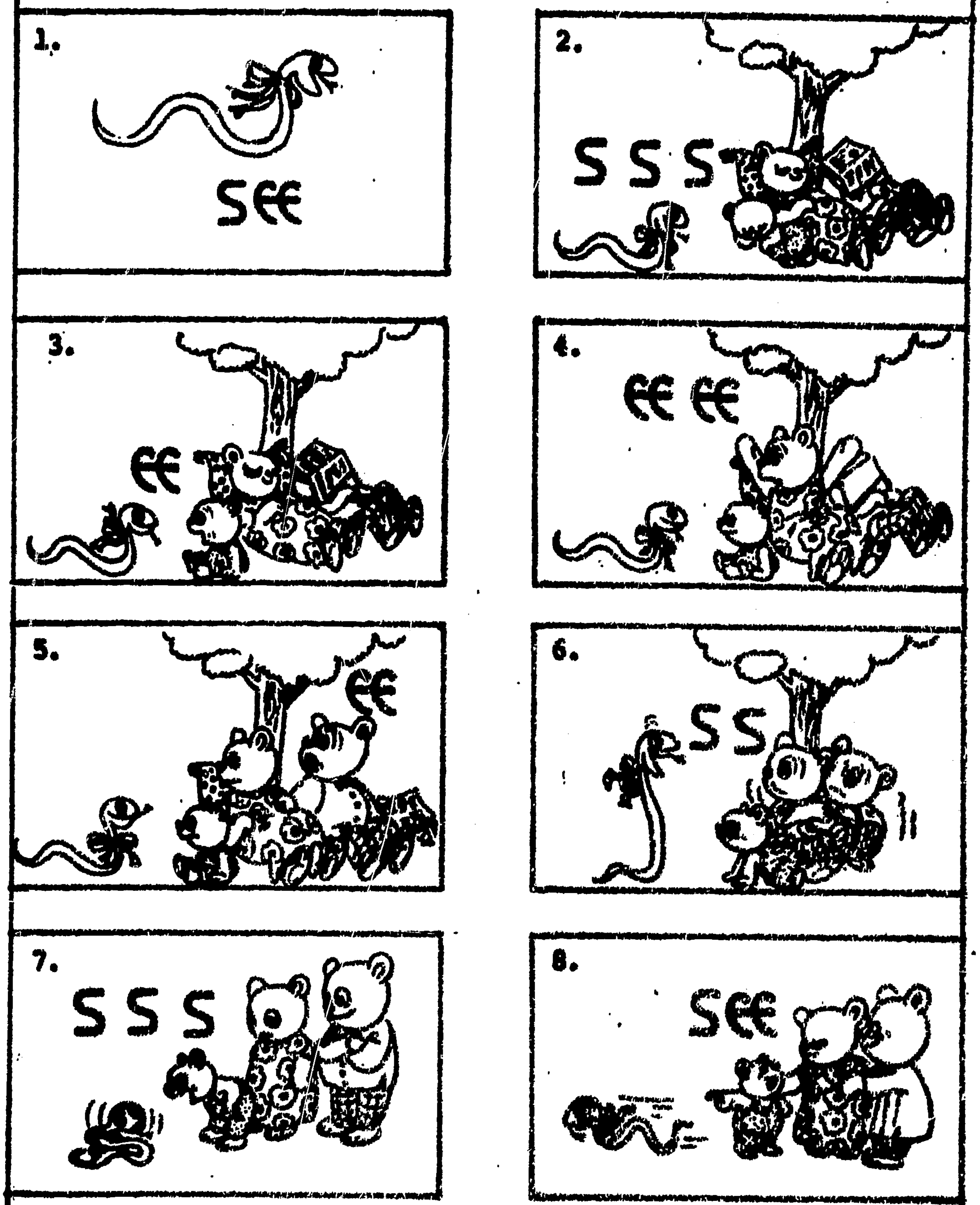

FIG. 4. EXCERPTS FROM A BOOK THAT ILLUSTRATES A TECHNIQUE THAT CAN BE USED FOR TEACHING PHONICS WHEN THE COMPONENT SOUNDS OF THE WORDS CAN PLAY A MEANINGFUL ROLE IN THE STORY.

By far the most difficult skills to teach in phonics and spelling are sound-blending and sound-analysis. They are almost impossible to teach if the first words contain many stops /p,b,t,d,k,g/ because these phonemes are impossible to pronounce in isolation; the child inevitably learns sounds such as puh and buh. We should not be surprised that the child has difficulty in seeing the relation between duh i-i guh and dig. It is far easier to approximate the sounds of the continuants in isolation /s,m,sh,z,etc./. The isolated sounds s-s-s ee-ee do not differ very much from see. In fact, by tape-recording such isolated continuants and by splicing progressively shorter strips of leader between them, this reading program has a tape in which the isolated sounds (s ee, s ee, see) gradually blend into the whole word with no qualitative jumps between the isolated sounds and the whole word. The value of such a tape for teaching sound-blending and sound-analysis should be obvious to any elementary teacher. Such a tape is practically--perhaps actually--impossible for words containing stops.

A SELF-CORRECTING STRATEGY FOR REFINING THE PROTOTYPE

The purpose of this paper is not to enumerate the virtues of the present psycholinguistic reading program. At present, it is still a rapidly evolving prototype based upon an inadequate data base--based more upon guesses than data.

The major purpose of this paper is to discuss research strategies for refining the present program. One strategy for refinement is a self-correcting cycle of test-refine-test-refine. Any research assistant who has shaped a number of animals in a Skinner box is aware that his teaching ability increases rapidly.

It may take him an hour or so to shape his first animal to press the bar, but he will probably be able to shape his second animal in half the time. As he teaches the animal, the animal is teaching him to teach.

We have a team of psychologists each teaching an individual child to read. The children, of course, are teaching the psychologists to teach; they are teaching us how to refine the reading program. But reading is more complicated than bar pressing and teaching ability does not increase quite as rapidly in the case of reading.

Part of the problem is time. It takes so long to teach a child all the subskills of reading that by the time a psychologist finishes with his child, he has forgotten many of the teaching techniques he learned at the beginning. There are several ways to alleviate the time problem.

Almost every response the child makes is recorded, and many of the sessions are video-taped. These tapes provide an unusually complete record. Furthermore, by cutting two-minute strips from successive lessons, we can splice them into a single tape that compresses a history of a child's successes and failures into a manageable time span.

Another technique for shortening the time span is to reinforce the child for every response. This permits longer and more intensive training sessions.

The children are started at different times. At any time, there is a child in the laboratory who is just beginning, another who has been reading for two weeks, another who has been reading for four weeks, and so on. This, of course, is another technique for compressing the reading process into a manageable time span. On any day, the team of teachers can observe a child at any stage of learning.

We hope to make fundamental improvements in the self-correcting research strategy. We hope to develop techniques for recording complicated responses as immediately interpretable displays. We hope to develop better techniques for compressing a history of interlocking responses into a manageable time span.

This self-correcting cycle of test-refine-test-refine is making many improvements in the program. There are cases, however, when the self-correcting strategy alone is a relatively inefficient technique for refining a product. It is essentially a honing operation--a polishing operation. It can be compared to a razor strop. It does not cut deep; it seldom leads to fundamental reorganizations. If one's beginning product is a piece of junk, ten years of polishing yields no more than polished junk.

To make fundamental reorganizations in the reading program, we need fundamental knowledge about the reading process. We need an adequate data base.

A PSYCHOLINGUISTIC DATA BASE FOR AN EDUCATIONAL TECHNOLOGY

The major purpose of this paper and its few experiments is to advocate collecting such a data base--a psycholinguistic data base upon which we can found one educational technology--a technology for constructing elementary reading materials.

There are characteristics of printed materials that increase or decrease their teaching capacity. By manipulating these characteristics, the pre-preprimer of Fig. 1 was simplified to the extent that a five-year-old could learn to read it in about

20 minutes. Scattered through the literature of verbal learning are thousands of experimental studies of such characteristics, e.g., studies of inter-item similarity, word frequency, etc. However, since these studies were usually performed upon college sophomores memorizing nonsense syllables, almost none of their data are in a form that would help an education engineer manipulate characteristics of printed material to increase its teaching efficiency. If the studies were replicated upon five- and six-year-olds learning reading responses to English letters, phonemes, and common words--if they were replicated upon relevant learner populations and relevant language populations--they would provide much of the data base needed to engineer elementary reading materials.

Replicating these studies will provide a set of functional relations, relations that plot the effect of a prose characteristic upon a reading skill, or more abstractly, S-R relations that plot the effect of a Stimulus-dimension upon a reading Response.

One way to conceptualize the final form of the needed data base is to visualize it as a systematic matrix of S-R relations. Linguistics and the psychology of verbal learning provide a taxonomy of S-dimensions. There is also available--but in less complete form--an array of Response measures. It is irresponsible not to relate the two.

As soon as one considers the number of subskills (or subresponses) that make up reading and the number of S-dimensions that affect these subresponses, it becomes clear that collecting this matrix of S-R relations calls for a massive research effort. A data base of this size must be collected systematically.

Years could be wasted by an unsystematic attack. The replications mentioned above will not provide all the needed relations. Unfortunately, no one has yet related many important S-dimensions to reading responses. More important, no one has yet developed efficient techniques for measuring crucial reading responses--responses such as comprehension, aesthetic appreciation, critical evaluation, and the information gained by reading a passage.

A systematic approach would begin by collecting S-R relations spotted at equal distances from one another throughout the matrix. If no coherent pattern emerged, intermediate relations would be collected. Finally, a pattern would emerge and the gaps would be bridged by interpollation.

Clearly, the research strategy for spotting the first S-R relations at more or less equal steps throughout the matrix is important. One way to spot them is according to reading responses.

At an early stage, reading comes to include responses such as understanding, aesthetic appreciation, and critical evaluation. We are a long way from defining such responses, much less developing measures for them that are accurate, valid, sensitive, and economical. And to collect the huge matrix of S-R relations advocated here, the measure of behavior must be economical; we must be able to mass produce experiments.

Therefore, it seems obvious that we must begin with the more mechanical skills of reading--those that are most important during the first year. Many--probably most--of these skills can be analyzed into paired-associate learning and the simpler forms of concept induction.

Much is known about measuring these skills. Ever since the publication of Ueber Das Gedächtnis in 1875, psychologists have spent much of their time measuring these kinds of behavior. There are sharp speculative instruments for analyzing these skills, precise research techniques for studying them, and most important, a huge--though unsystematic--scattering of S-R relations that relate S-dimensions of language to such responses.

In their present form, these S-R relations are almost useless to a technician trying to manipulate the S-dimensions of printed material that increase its teaching capacity. The relations are described with a confusing jargon of intervening variables and hypothetical constructs. Their data are based upon college sophomores memorizing nonsense syllables. It is shortsighted not to replicate these experiments and transform their data into a form that could become part of a technology

CALIBRATING LINGUISTIC UNITS AS TO LEARNABILITY

Suppose the written Communication Skills are conceptualized as a finite list of concepts and associations (see Fig. 5). Each concept, which must be partly induced, has a list of low-order associations which must be memorized. The child needs all the concepts very early, but a frequently used association (f is pronounced /f/) is more useful to the child than an uncommon one (gh is pronounced /f/); an easily learned skill (discriminating w from s) will take less time than a difficult one (discriminating b from d). More generally, a carefully engineered reading program would begin by teaching the most learnable and most useful concepts and associations. By considering usefulness and learnability in sequencing what we teach the child, each burden of learning we impose upon him will yield maximum payoff in number of words he can enjoy in actual reading. More important, by sequencing the low-order associations, the program can facilitate the child's induction of the high-order concepts. The concepts underlying phonics are very difficult to induce from some sets of words, but fairly easy from others. Thus, a major purpose for collecting the matrix of S-R relations is that it calibrates the various linguistic units according to ease of learning.

The printed communication skills, however, are a complex, interlocking hierarchy of subskills. Unfortunately, a set of

1. Read from left to right.

2. Printed words stand for spoken words and different word shapes stand for different word sounds.

    a. the shape "see" signals the sound /see/.

    ⋮

    n. the shape "national" signals the sound /national/.

    ⋮

    x. the shape "fenchone" signals the sound /fenchone/.

⋮

6. Printed words can be analyzed into letters and different letters stand for different sounds.

    a. the letter "s" signals the sound /s/.

    ⋮

    n. the letter "f" signals the sound /f/.

    ⋮

    x. the letters "gh" signal the sound /f/.

⋮

FIG. 5. THE COMMUNICATION SKILLS CONCEPTUALIZED AS A FINITE LIST OF CONCEPTS AND ASSOCIATIONS TO BE TAUGHT. BY SEQUENCING THE LOW-ORDER ASSOCIATIONS ACCORDING TO LEARNABILITY, THE READING PROGRAM CAN FACILITATE THE CHILD'S INDUCTION OF THE HIGH-ORDER CONCEPTS.

materials that is easily learned according to one subskill may be very difficult to learn according to another. The words in the vowel-by-consonant matrix of Fig. 6 (taken from Houghton-Mifflin's first preprimer, Tip) are easy to learn according to whole-word, look-and-say learning. It should be apparent by studying the number of letter-sound associations and the number of different sounds attached to the vowels, however, that this set of words would be very difficult to learn to spell or sound out.

Letter	e				o			a		i		ou	ay
Sound	e	ė	ē	e	o	ō	u	a	aw	i	ī	oo	a
Consonant													
t										Tip			
p										Tip			
n					not	no							
h		here		here									
r		here											
c							come						
m			me										
J	Janet							Jack					
k													
s										is			
w										with			
th										with			
f											find		
d								and					
g						go							
b									ball				
l										will			play
y												you	

FIG. 6. VOWEL-BY-CONSONANT MATRIX TAKEN FROM TIP. ALTHOUGH THESE WORDS WOULD BE EASY TO LEARN ACCORDING TO LOOK-AND-SAY LEARNING, THEY ARE VERY DIFFICULT TO LEARN TO SPELL OR TO SOUND OUT BECAUSE THERE ARE MANY DIFFERENT LETTER-SOUND ASSOCIATIONS AND BECAUSE THERE ARE SEVERAL DIFFERENT SOUNDS ATTACHED TO SOME OF THE VOWELS.

The matrix of Fig. 7, on the other hand, is easy for spelling or phonics; it only requires the child to learn seven print-to-sound associations. Unfortunately, its words are very difficult to learn by whole-word memorization. Because the words are so similar, their shapes are hard to discriminate from one another. Also, many of them are hard to learn because they occur infrequently in English.*

Vowel / Cons.	ee	a	i
s	see seem	Sam Sal	Sis
m	mee man	am	Miss mill Min
l	Lee eel lass lam	Al	ill
n		Ann	

FIG. 7. A VOWEL-BY-CONSONANT MATRIX THAT REQUIRES THE CHILD TO LEARN ONLY SEVEN PRINT-TO-SOUND ASSOCIATIONS. ITS WORDS ARE DIFFICULT TO LEARN BY LOOK-AND-SAY LEARNING, HOWEVER, BECAUSE THE WORDS ARE HARD TO DISCRIMINATE FROM ONE ANOTHER.

Figures 6 and 7 may explain the conflicting conclusions given by experimental comparisons of look-and-say techniques versus phonics. If an experimenter is inclined (consciously or unconsciously) to prove that phonics is the better method; he need only select (consciously or unconsciously) a sample of words similar to Fig. 7. To prove that look-and-say is better; select words similar to Fig. 6.

By simultaneously considering learning according to whole-word memorization, and spelling, and phonics, and printing, we would start with a set of words more like those of Fig. 8.

Vowel / Cons.	ee	a	i
S	see seem seen	Sam	sit Sis
M	mee	man am Mat	mitt Miss
N		An an	in
th	thee	that than	thin this
t		sat	it

FIG. 8. A VOWEL-BY-CONSONANT MATRIX WHOSE WORDS WERE SELECTED BY SIMULTANEOUSLY CONSIDERING LEARNABILITY ACCORDING TO LOOK-AND-SAY LEARNING, AND SPELLING, AND PHONICS.

In short, given a matrix of S-R relations, an education engineer could calibrate linguistic units for several kinds of learnability. Then he could select his units to maximize learnability according to all subskills considered simultaneously.

Furthermore, he could combine in optimal proportions the techniques for making material more learnable. For instance, there are two techniques for regularizing English and making words easy to sound out--the Initial Teaching Alphabet and Bloomfield's linguistic system. Each has great disadvantages. The Initial Teaching Alphabet misspells about 75% of the words and some 40% of these misspellings are radical ones (Fig. 9). Bloomfield's linguistic system is woefully lacking in function words such as <u>would</u> and <u>was</u>; thus, many of its sentences are such awkward ones as "<u>Fat Pat sat on the mat.</u>" (Fig. 10)

> ie hav just cum from a scool whær ſhe nue reedin is taut. ie met ſhær a littl girl ov siks. ſhee is ſhe œldest ov a larj family livin on an œldham housin estæt. tco yeers agœ ſhee wos a ſhie nervus chield, tco frietend tco tauk. ſhee has wun priezd personal posseſhon—a dog-eerd anthology ov vers, given tco her bie an œlder chield. ſhat littl girl ov siks has just red tco mee very buetifully wurdswurth's daffodils. ie askt her whie ſhee chœs ſhat pœem. ſhee replied ſhat ſhee luvd daffodils.

FIG. 9. AN EXAMPLE OF THE INITIAL TEACHING ALPHABET. IT MISSPELLS ABOUT 75% OF THE WORDS AND SOME 40% OF THESE MISSPELLINGS ARE RADICAL ONES.

BLOOMFIELD'S SYSTEM

Did an ant and a bug romp in a bin?
Yes, but the ant and the bug
had a scrap.
Did the ant jump on the bug?
Yes, but the bug ran and left
the ant on the damp sod in the bin.

FRIES' SYSTEM

Dan had the bat.
He bats and tags the bags.

FIG. 10. EXAMPLES FROM LINGUISTIC READERS. LINGUISTIC SYSTEMS ARE LACKING IN FUNCTION WORDS AND THEIR SENTENCES TEND TO BE AWKWARD ONES.

Given the data base advocated here, an education engineer could combine the two techniques in proportions that would give almost all (95% ?) of the advantages of each and almost none of their disadvantages. He could select all the nouns, verbs, and adjectives from Bloomfield's list so that 99% of the words were properly spelled, but he could supplement them with a very few function words misspelled in a transitional alphabet so he could get idiomatic sentence patterns such as Fig. 11.

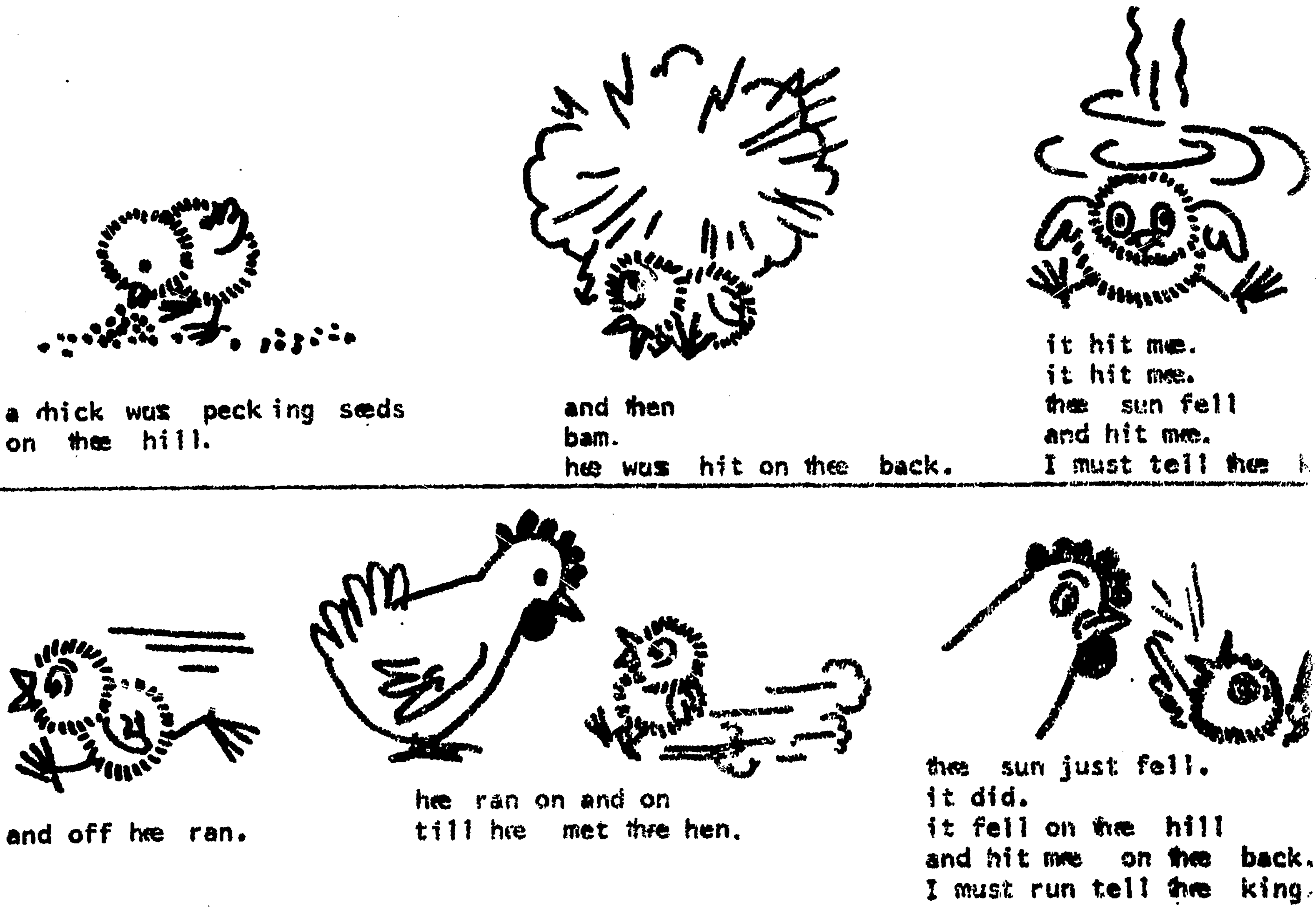

FIG. 11. READER THAT COMBINES FEATURES OF THE ITA AND THE LINGUISTIC SYSTEM TO GET IDIOMATIC SENTENCE PATTERNS BUT ONLY A FEW MISSPELLINGS.

ANALYSIS INTO SUBSKILLS

The complex hierarchy of skills that underlie reading, printing, and spelling can be analyzed in many ways--in many terminologies. The S-R terminology of the psychology of verbal learning provides one promising way because it rests upon approximately one hundred years of sustained experimentation. Computer terminology suggests an interesting elaboration. An information processing system such as a computer (or a human brain) has two ways to provide information from itself:

1. *It can draw it from a file. In reading, this means that a word shape had to be memorized as a whole. In spelling, it means that a sequence of letters had to be memorized as a whole.*
2. *It can synthesize it by combining smaller bits of information according to rules. In reading, this means synthesizing words from sounds (sounding out). In spelling, it means synthesizing words from letters (spelling them).*

Figure 12 has categorized the more mechanical subskills according to this dichotomy.

Note that the majority of the subskills can be conceptualized as ordinary paired-associate learning. Paired-associate learning can in turn be analyzed into three stages: (1) discriminating the stimuli from one another, (2) making the responses available in the learner's repertoire, (3) pairing the stimuli and responses appropriately.

	EVERYDAY NAME	COGNITIVE OPERATION	STIMULUS	RESPONSE
STORING KNOWLEDGE PA MEMORIZATION	Look-And-Say Learning Word-Shape Memorization	Paired-Associate Memorization	Child sees printed word; he sees word-shape as a whole.	He says word, recognizes whole word-shape.
	Printing	PA	Phoneme	Print Letter

SYNTHESIZING KNOWLEDGE FROM RULES: CONCEPTS *A high-order unit is analyzed into sub-units, a response is made to each sub-unit according to general rules, and then the responses are synthesized into a new high-order unit.*	Sounding Out A Word	Prerequisite PA Learning	Child sees letter.	He says phoneme.
		ANALYSIS *(of print)*	Child sees printed word.	Analyzes into sequence of letters, and/or syllables, and/or morphemes.
		MAP	Sequence of letters, and/or syllables, and/or morphemes.	Maps into *(Says)* sequence of phonemes, syllables, morphemes.
		SYNTHESIS *(auditory blending)*	Child hears sequence of isolated sounds *(that he says himself).*	Blends into word-sound.
	Spelling	Prerequisite PA Learning	Child hears phoneme.	Gives letter.
		ANALYSIS *(auditory)*	Child hears word.	Analyzes into sequence of phonemes.
		MAP	Sequence of phonemes *(that he says himself).*	Maps into sequence of letters.
	Blend Words Into Phrases And Clauses.	SYNTHESIS	Sequence of words.	Blends into meaningful phrases and clauses. Gives proper stress, juncture, intonation.

FIG. 12. STIMULUS-RESPONSE ANALYSIS OF SKILLS REQUIRED IN THE COMMUNICATION SKILLS. ASSUME A SUB-LANGUAGE SUCH AS THE ONE OF FIG. 2 THAT IS DESIGNED TO HAVE NO SPELLING OR PHONIC IRREGULARITIES.

The psychology of verbal learning and the science of linguistics have considerable information about learning such skills. There is information about the stimulus dimensions that affect the learnability of the materials, the units involved, age of sufficient maturity, sequence of development of linguistic skills, and so on.

If space were available, Fig. 12 could be analyzed in much greater detail. Then each cell could be filled with experimental data that discusses the learning of the particular skill. Figure 13 examines one row--the first row in sounding out a word in which the child sees a letter and says its phoneme. Column 1 lists hypothetical constructs that affect discriminating the stimulus and that affect response availability. Column 2 lists practical applications for increasing the teaching efficiency of printed materials.

Variable Expressed as a Hypothetical Construct	Example of an Application
1. Stimulus Discriminability.	Calibrate sets of letters as to discriminability and begin with sets that are easy to discriminate from one another, e.g., don't have pairs such as d-b or p-q in first materials.
a. Number of criterial dimensions that distinguish the stimuli.	Alter the alphabet slightly so as to increase the dimensions that distinguish frequently confused pairs, e.g., h-N instead of h-n, L-i instead of l-i, p-q instead of p-q
b. Number of irrelevant dimensions that affect the stimuli.	Eliminate serifs
2. Response Availability	Calibrate the responses (the phonemes) and begin with the most available ones. Begin with familiar sounds, do not begin with difficult phonemes such as <u>th</u>.

FIG. 13. FURTHER ANALYSIS OF A SINGLE ROW OF FIG. 12--THE CHILD SEES A LETTER AND SAYS THE PHONEME. COLUMN 2 LISTS APPLICATIONS FOR IMPROVING LEARNABILITY.

Let us illustrate the sort of experimental data that is needed before we will be able to manipulate characteristics of printed material so as to increase its teaching efficiency. Consider, for example, one variable that affects one small part of one cell in Fig. 12. Consider one small step in teaching a child spelling--teaching him to give the letters associated with each phoneme. Consider one substep in that small step--teaching him to discriminate the stimuli (the phonemes) from one another. Consider just one variable that scientific experiments have shown to affect this substep--stimulus similarity. The academic scientist can be satisfied when he shows that stimulus similarity of nonsense syllables affects paired associate memorization by college sophomores. An education engineer needs more data and finer detailed data. First he needs to calibrate the particular stimuli of interest as to similarity using six-year-olds, i.e., he needs a confusion matrix for the English phonemes (probably several confusion matrices--different ones for each dialect). With this information, perhaps he could begin to order the phoneme-letter pairs in their most learnable sequence (probably ordering them as to ease of learning), but certainly he would need data from many additional experiments before he could design an adequate set of materials.

Samples and Experimental Designs.

An experiment designed to calibrate the ease of learning the print-to-sound relations (giving the sound when shown the letter) can illustrate the required experimental design. We need an experimental design that permits simultaneous generalization across two populations--a population of learners and a population of language materials. Rather than measure the difficulty of learning each print-to-sound relation, it seems more practical to begin with a broad band experiment that will provide a large percentage of the information we need. Let us call such an experiment a First-Generation Experiment. We will begin by comparing the learnability of broad phoneme categories--stops, fricatives, affricates, nasals, glides, and vowels. By testing a small sample of children, each learning a small sample of phonemes representing the above categories, we wish to be able to generalize across the entire population of children and the entire population of English phonemes. The most economical statistical design in this case confounds the two sampling variables, and allows us to generalize from a relatively inexpensive experiment in which two or three dozen children each learn six to eighteen print-to-sound pairs.

The essentials of the design are that a sample of children is drawn and each child learns six print-to-sound PA's (one

RESEARCH METHODOLOGY

When one examines the cells of Fig. 12, considers the further analysis that is possible, and reflects upon the number of stimulus dimensions that affect each cell, it becomes obvious that collecting all the data necessary to found a technology of educational engineering will require a massive research effort. Psychology and education must increase the scale, precision, and efficiency of their data collection many times over. This is well within the realm of possibility because many of the experiments have already been performed, but upon irrelevant populations--upon samples of college sophomores and upon samples of nonsense syllables. Replicating these experiments upon relevant populations should be within the capacity of an MA technician who has specialized in the experimental techniques of the behavioral sciences.

We must collect information at many times the rate of the university scholar. This need not occasion dismay. These function-collecting experiments are simple ones. By specialization and by utilizing sophisticated instruments, a properly trained MA can collect a hundred times the data collected by far more insightful university scientists.

A rat can be placed in a Skinner box, and as the experiment proceeds, the cumulative recorder prints out an interpretable display. In this age of computers, there is every reason to believe that we can design instruments that will print out displays that have already been averaged or analyzed in other ways.

involving a stop, one involving a nasal, one involving an affricate, etc.) but the phoneme used to represent each phoneme class is different for each child.

Such an experiment as the above, simple and economical as it is, will provide us with a large part (say 25%) of the information that we need about the relative learnability of the print-to-sound relations.

On this information alone, an insightful writer of instructional materials could put together a set of lessons. But more detailed information would decrease the need for insight and the amount of false starts.

The more detailed information would require additional experiments that sample from more narrowly defined phoneme populations (that rank learnability of all English phonemes) or that draw from more narrowly defined subject populations (e.g., Spanish-speaking Americans from homes in which Spanish only is spoken). Clearly, each additional experiment will not provide 25% of our needed information; information value will drop progressively, but the smaller amount of information will be offset by the fact that each individual experiment will become cheaper as more of them are performed.

Data-Collecting Strategy

If we superimpose the available scientific information upon our S-R analysis, some simple tallying plus an acquaintance with available data will show the missing data we must fill in before we can engineer the learning tasks--before we can order the learning tasks in the most learnable sequence--before we can order the low-level tasks in a sequence that will minimize the effort required to induce the more general conceptual skills.

A considerable amount of the needed information can be collected by economical, broad-band experiments--our First Generation Experiments. They employ the most useful dependent variable, draw from a broad subject population, and compare broad classes of the language population. Later, we must perform more finegrained Second and perhaps Third Generation Experiments that analyze subject populations and measure other dependent variables.

In the case of printed stimuli (words and letters), we can go a step beyond; to a limited extent, we can alter them to improve their learnability (e.g., we can use ligatures such as th , sh , and ch ; combine letters from different fonts; space them into subunits; even redesign the letters to a very limited extent).

Short-Range Plan for Beginning a Useful Data Base.

Using relevant subject populations (six-year-olds) and relevant language populations (phonemes, letters, 1,000 most common regular words), we must measure the ease of learning the relevant responses to each representative of the language population (e.g., learning a discrimination response to each letter, learning a pronunciation response to each function word, etc.). With these data we can calibrate the stimuli according to ease of learning the response.

Specifically, we must perform experiments that measure:

1. the ease of blending combinations of different phonemes
2. the ease of analyzing combinations of different phonemes
3. the ease of learning to pronounce each letter (letter-phoneme PA)
4. the ease of learning to give a letter as a response to each phoneme (phoneme-letter PA)
5. the response availability of each isolated phoneme (free recall a list)
6. the learnability of function words, nouns, verbs, adjectives (with word frequency as a parameter)
7. the auditory discriminability of each phoneme
8. the comparative ease of analyzing pre-analyzed and unanalyzed printed words
9. the comparative ease of reading pre-analyzed and unanalyzed sentences
10. the visual discriminability of different word shapes
11. the ease of learning to print each letter
12. the visual discriminability of each letter

SUMMARY AND CONCLUSIONS

1. The major thesis of this paper is that it will be possible in the near future to reduce to a technology one important part of education--constructing materials for the printed communication skills in the first grade. This technology requires a data base--a huge matrix of S-R functions that plot the effect of an Stimulus-dimension upon a reading Response. A considerable portion of the data base can be provided by replicating previous experiments, but upon relevant learner populations and relevant language populations.

Among other things, this data base would calibrate linguistic units as to learnability. Then an education engineer could order the low-order tasks of reading into a sequence that would facilitate the induction of more general concepts such as those of phonics and spelling.

2. To collect a data base of this magnitude, education and psychology must increase the efficiency of their research techniques many times over. Just as Skinnerians have learned to mass produce experimental studies of animals learning bar presses, we must learn to mass produce experimental studies of children learning more complicated responses.

3. To collect a data base of this magnitude, education must produce cheaper and more efficient data collectors--probably MA's with strong backgrounds in linguistics and experimental psychology.

A complementary strategy for producing materials is by refining a prototype through a self-correcting cycle of test-refine-test-refine. Considerable improvements need to be made in this research strategy. We need techniques for recording complicated responses as immediately interpretable displays. We need techniques for compressing a history of interlocking responses into manageable time span. The secondary purpose of this paper was to describe a rapidly evolving prototype called the psycholinguistic reading program.

The present form of the psycholinguistic reading program is based largely upon calculated guesses. But given the matrix of S-R relations advocated here, education could engineer a "New Reading"--a new reading that might be as revolutionary as the New Math.

The program is still a long way from this. Even with its present lack of polish, however, placed on a preschool television program in the form of animated cartoons, it could teach most of the five-year-olds in the United States to read before they enter school. Of course, we can not teach preschoolers to read hundreds of different words, but if the right words are selected, a dozen or so are enough. A dozen or so can teach all the basic concepts underlying reading, spelling, phonics, and printing. Hundreds of pre-preprimers should be made available as inexpensive comic books and coloring books--perhaps as syndicated comic strips in the newspapers. Our children can be accomplished masters of all the basic concepts of reading when they enter the first grade.

We have a multi-billion dollar tool for preschool education in our television system. That tool, wedded to a series of animated cartoons and a series of pre-preprimers beginning with ones as simple as Fig. 1, could extend Operation Head Start into Operation Running Start--a running start for all our preschoolers.

COLLECTING A DATA BASE FOR AN EDUCATIONAL TECHNOLOGY:

II. DECREASING THE CONFUSIONS BETWEEN CERTAIN LETTER PAIRS

There are many typographical alterations that might improve the learnability of elementary reading materials:

1. *Slight alterations might be made in certain letters to increase the differences between frequently confused letter pairs such as p-q, p-b, and u-n.*
2. *Slight alterations might be made in a few letters to increase the differences between word shapes. That is, differences between word shapes would be increased if the number of upward-protruding, downward-protruding, and non-protruding letters was roughly equal and if the number of angular and curved letters was roughly equal. Specifically, the alphabet needs more angular letters and more downward-protruding lette*
3. *The difference between upper and lower case letters might be decreased. At present, the child has to learn 40 different letter shapes because upper and lower case differ considerab for a, b, d, e, f, g, h, i, l, m, n, q, r, and t.*
4. *Spacing might be designed to reflect linguistic units more closely. For instance: (a) use ligatures for sh, ch, th, qu, ou, ie, etc. (b) use only a half space between an artic and its noun, (c) half space between morphemes, (d) use two spaces between words, (e) use only one clause to a line.*

It should be possible to design a transitional typography with the above characteristics that would create almost no negative transfer for first- and second-graders. There are a number of different type fonts a person must master in his lifetime. Simply by choosing letter from different fonts, we can create an alphabet with most of the above characteristics. We would not be imposing any additional learning or unlearning on th child; we would just be altering the sequence for introducing the different letter shapes.

The present investigation will be principally concerned with the first alteration, but the others influence the choice of modified letter shapes. A study by Popp (1964), which agreed in general with previous studies, rank-ordered the 15 most frequently confused letter pairs as follows: p-q, d-b, b-q, d-p, b-p, h-u, i-l, k-y, t-u, c-e, h-n, h-y, j-k, n-u. This experiment will test alterations designed to decrease the confusions between p-q, d-b, i-l, n-u, and p-b.

Procedure

Experimental design. The study is best conceptualized as five separate 2-by-14, treatment-by-subject designs. The two treatments were the traditional and experimental letter pairs of Fig. 1.

Materials. The five pairs and their experimental versions are given in Fig. 1. The rationale of the several alterations is given in the first paragraph of this paper.

Subjects. The subjects were 14 non-reading preschoolers whose ages ranged from 52 months to 70 months.

Presentation. One letter from a pair was projected for .10 sec. Then the child was shown the pair and asked to select the letter tha had been projected. The child was presented with each letter of Fig eight times.

Results

Percentage of correct identifications is given in Fig. 1. The significance of the difference between each experimental letter pair and its traditional counterpart was tested separately as though there were five separate experiments. As might be expected, there were significantly fewer confusions for the experimental pairs for all five comparisons ($p < .01$ by Wilcoxon T tests).

There is little need for prolonged discussion of the results. Slight alterations would decrease the confusions between letter pairs that give first graders the most difficulty. Note that the children averaged little better than chance (50% right and 50% wrong) when distinguishing between the reversed letter pairs of the traditional alphabet--p-q, d-b, u-n.

TRADITIONAL		EXPERIMENTAL	
Pair	%	Pair	%
db	44%	db	91%
pq	52%	pq	82%
il	69%	il	83%
un	57%	UN	84%
bp	68%	bp	86%

Fig. 1. Five experimental letter pairs and their frequently confused traditional counterparts given with their percentage of correct discriminations.

References

Popp, Helen M., Visual discrimination of alphabet letters. Reading Teacher, 17, 1964, 211-227.

COLLECTING A DATA BASE FOR AN EDUCATIONAL TECHNOLOGY:

III. CALIBRATING LINGUISTIC UNITS AS TO USEFULNESS.

An efficiently engineered reading program would sequence the units to be taught according to usefulness and according to ease of learning. If this were done, each burden of learning imposed upon the child would give maximum payoff in number of new words he could read and enjoy. More important, he could induce the higher-order concepts such as phonics after he had memorized a minimum number of lower-order skills such as the letter-sound associations.

In the psycholinguistic reading program, we begin by teaching the child a small number of letter-sound associations (ee, a, i, s, m, n, final t, and th) and the more common three-sound words that can be generated from these letters. Suppose we have already taught a child eight letter-sound associations. Which one should we teach him next? We expressed the question in operational terms as follows (although we qualified it with certain hunches about ease of learning): "Which grapheme will combine with the above eight to add a maximum number of common words?"

Qualifications we attached to the question were:

1. *Shortness. We restricted our population of words to those of three sounds or less (am, run, bout) that contained no consonant clusters.*

2. *Regularity.* We restricted the population to regularly spelled words except that the final silent e that lengthens the preceding vowel was considered regular (*mate*, *rope*, etc.).

3. *Phonic Blendability.* Although there is as yet little direct evidence on the question, it was assumed that words composed of continuants were easier to teach than those containing stops or affricates, and that words containing final stops were easier than those containing initial stops.

Procedure

We generated 1190 regularly spelled, three-sound words that contained no consonant clusters from the following graphemes: a, e, i, o, u, ee, ou, oo, oa, ea, ow, ar, ei, ay, oy, aw, oi, aCe (a Consonant e as mate, sane), eCe, iCe, oCe, uCe, the final stops and affricates (p, b, t, d, k and ck, c, g, ch, j), the initial stops and affricates, s, m, n, th, h, wh, r, f, l, w, sh, y, j, v, z, x, qu.

Sequencing According to Number of Added Words.

In Phase I, the three-sound words containing no stops (except final t), no affricates, and no final e were punched into the computer. Specifically, we punched in the words generated from ee, a, i, s, m, n, th, final t, l, w, r, y, f, v, z, sh, wh, o, u, e, oo, ea, ar, aw, ow, ay, ey, oy, ei, ai, oi, ou. Then the computer was asked: "Given that we already have the graphemes, ee, a, i, s, m, n, th, and final t, what is the next letter that we should add to our program? That is, which grapheme will combine with these eight to add a maximum number of regular words. The computer tried each of these additional graphemes (l, w, r, etc.), and answered that l would combine with the above eight to add a maximum number of new words (eel, ill, lam, lass, lath, Lee, lit, mill, Sal, sill). So l was added to ee, a, i, etc., and the question was repeated until the computer had rank-ordered the next nine graphemes (ea, h, u, sh, r, f, oo, e, ou).

These ten graphemes, plus the eight original ones, give a total of 199 words in the program at this point. It was assumed that by the time a child had mastered the greater number of these words, he would be ready to deal with final stops, final affricates, and the final e that lengthens the preceding vowel.

In Phase II, therefore, all the words containing these graphemes were added to the computer's pool of words. We continued asking it the same question, "What is the next grapheme to add that will combine with those already in use to generate a maximum number of new words?" It selected the final d (which added 36 new words), and the question was repeated until it had selected nine additional graphemes, giving a total of 28.

At this point, the program contains 499 words, and it was assumed that even a small fraction of this number would have given the child sufficient practice in reading to enable him to master initial stops.

In Phase III, therefore, all the words containing initial stops and affricates were added to the computer, and we continued asking it the same question until it had generated the sequence for introducing all our graphemes.

Sequencing According to Summed Frequency of Usage for Added Words.

The above sequence was determined entirely by the total number of words added by a grapheme. We also generated a sequence that was determined by the words' frequency of usage. The frequency of usage by first-graders according to Rinsland for each of the 1190 words was punched into the computer and the same three phases were carried out with one exception. Instead of the next grapheme's being selected according to the total number of words it added, it was selected according to their summed frequency of usage. That is, each time the computer tested a new grapheme, it combined it with the previous ones to generate the additional words. Then it summed the Rinsland frequency of usage and used that total in selecting the next letter to add, for all the new words.

Sequencing According to Number of Words and Summed Frequency.

We also generated a sequence that was determined jointly by number of additional words and by their frequency of usage. In selecting the next grapheme, the total number of added words was multiplied by 50, and this product was added to their summed frequency of usage. This weighting gave a sequence that was roughly midway between the other two.

Results

The sequences were:

Sequencing According to Number of Added Words.

<u>Beginning Eight Graphemes</u>. s, ee, m, a, i, final t, n, th.

<u>Phase I</u>. l, ea, h, u, sh, r, f, oo, e, ou.

<u>Phase II</u>. final d, oCe, aCe, final p, final k and ck, iCe, w, ar, v, ai.

<u>Phase III</u>. initial d, p, t, k (i.e., all stops that had already been introduced in final position), b, g, ch, o, c, uCe, J, z, ow, wh, aw, y, ay, x, oi, qu, oe, eCe, ie, oy, ue.

Sequencing According to Summed Frequency of Usage.

<u>Beginning Eight Graphemes</u>. s, ee, m, a, i, final t, n, th.

<u>Phase I</u>. h, ou, o, e, sh, ow, oo, r, f, u.

<u>Phase II</u>. iCe, aCe, final d, eCe, w, l, final k and ck, ea, oCe, final p.

<u>Phase III</u>. initial d, p, t, k (i.e., all stops that had already been introduced in final position), c, g, b, oy, ar, ay, wh, aw, v, y, ai, ch, x, uCe, ie, qu, j, oi, z, oe, ue.

Sequencing According to Number of Words and Summed Frequency.

<u>Beginning Eight Graphemes</u>. s, e,, m, a, i, final t, n, th.

Phase I. h, ou, o, e, sh, oo, r, f, u, l.

Phase II. iCe, aCe, final d, eCe, w, final k and ck, oCe, ea, final p, wh.

Phase III. initial d, p, t, k (i.e., all stops that had already been introduced in final position), b, g, c, ow, ar, ch, v, ai, ay, oy, aw, uCe, j, y, z, x, qu, oi.

Discussion

The most satisfactory sequence is probably the one considering both number of additional words and their summed frequency of usage. This sequence is clearly only a first approximation. Pedagogical considerations suggest grouping some graphemes and teaching them as sets. They would suggest altering the sequence about as follows:

Beginning Eight Graphemes. s, ee, m, a, i, final t, n, th.

Phase I. h, ou plus ow, o, e, sh, oo, r, f, u, l.

Phase II. First introduce eCe as equivalent to the familiar ee. Then introduce iCe, aCe, oCe, and uCe together. Then introduce ie, oe, and ue as equivalent to iCe, oCe, and uCe respectively. Then introduce oa and ea as equivalent to oe and ee respectively. Then introduce final d, w, final k and ck, final p, and wh.

Phase III. Introduce initial d, p, k, t (i.e., all stops already introduced as finals), b, g, c, ar, ch, v, ai plus ay, oy plus oi, aw, j, y, z, x, qu. Then introduce ur, followed by er and ir as its equivalent.

Some such sequence will be used to develop a second generation prototype reading program which will be evolved into a more finely polished version using the self-correcting techniques discussed in the first paper of this series.

As the data base that was advocated in the first paper is collected, we will be able to order the graphemes into a more efficient sequence. In the computer program reported in this paper, the restrictions in the three phases were based more upon hunches than real data. Soon we should have information about the ease of blending different sounds that will allow a more precise set of restrictions. Soon we should have information about the most advisable time to introduce polysyllabic words and the most advisable time to introduce consonant blends. Soon we should have better information about grouping the vowel combinations into sets.

When enough of this information accumulates, it will be added to our computer program, and another sequence for introducing the graphemes will be generated. This sequence will be used to develop a third generation prototype reading program, which will be polished and evolved according to self-correcting techniques. And so on.