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ABSTRACT

The investigation was concerned with the class of grapheme-phoneme correspondence called spelling patterns and was intended to broaden empirical understanding of grapheme-phoneme correspondences used in teaching initial reading. Twenty-five boys and 47 girls from three moderate-ability first grade classes were chosen as subjects. These students had accumulated six minutes of session time on the computer assisted reading program (CAI) phonic strand before beginning the experiment. One set of 24 spelling patterns was devised for each of the five vowels: A, E, I, O, and U. When each subject began the experiment, he was randomly assigned to one of the five sets of spelling patterns and then 12 of the 24 spelling patterns in the chosen set were selected for training. At the end of his eight-day training period, each subject was individually tested, off-line, on all 144 initial consonant and final consonant combinations derived from the full set of 24 spelling patterns to which he was assigned. The data reflected the value of presenting spelling patterns in initial reading. Teaching spelling patterns to the subjects resulted in positive transfer to a criterion task that required subjects to read words and non-words composed of the spelling patterns taught. (WR)

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by

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TRANSFER FROM ALTERNATIVE PRESENTATIONS OF SPELLING PATTERNS IN INITIAL READING

J. D. Fletcher

This investigation was intended to broaden our empirical understanding of grapheme-phoneme correspondences used in teaching initial reading. As the title indicates, the investigation was concerned with a particular class of grapheme-phoneme correspondences called spelling patterns. Whereas grapheme-phoneme correspondences may refer to invariant associations of single graphemes with single phonemes, a spelling pattern is usually defined as a group of graphemes that in a specificable environment bears an invariant correspondence to its pronunciation (Gibson, 1965). Current notions of transformational-generative phonology (Chomsky and Halle, 1968) question the linguistic utility of this definition, but it suffices as a working definition for this investigation.

GRAPHEME-PHONEME CORRESPONDENCES IN INITIAL READING

In 1933, Leonard Bloomfield suggested that

> Two devices obviously demand to be tried. One is to teach children to read phonetic transcription, and to turn to traditional writing only after the essential reading habit has been set up. The other is to begin with graphs that contain only one phonemic value for each letter...and either postpone other graphs until the elementary habit has been fixed, or else to introduce them, in some rationally planned way, at earlier points [p. 501].

These ideas were not original in Bloomfield's time and they are not revolutionary in ours. The Initial Teaching Alphabet currently being implemented is antedated by a teaching alphabet developed by John Hart in 1570, and Richard Mulcaster's Elementarie was published in 1582 to argue for the regularization of English orthography that reading might be facilitated. The value of Bloomfield's two suggestions is not nullified by their lack of novelty; instead, their persistence may indicate their worth. Bloomfield's contribution was to advance these ideas when they were unpopular. His own reading series, which was based on his second suggestion, was not funded for publication until 1958, 21 years after it was developed and nine years after his death.

Bloomfield's second suggestion recommends the use of grapheme-phoneme correspondences in teaching initial reading. In practice, the 'graph' or grapheme can be a single letter, a syllable, or a word. In the Bloomfield and Barnhart (1961), Lippincott (1963), Merrill (1966), and Behavioral Research Laboratories, or Sullivan, (1967) readers, the initial grapheme-phoneme correspondences are VC syllables presented in words that are generally of a CVC configuration. VC words are also allowed early in these readers and Lippincott permits double consonant clusters (CCVC, CVCC, and CCVCC) as well as CV words. Evidently, development of these readers assumed that the basic grapheme unit used in initial reading should be larger than a single letter and smaller than a whole word.

Letter Name and Letter Sound Training

Knowledge of letter names does not seem to have a positive effect on reading acquisition. The Bond and Dykstra (1967) survey of first-grade reading instruction found that letter name knowledge was the single best 'predictor' of first grade reading success. Other studies by Wilson and Flemming (1937), Durrell (1958), and De Hirsch, Jansky, and Langford (1966) corroborate this conclusion with equally high correlations between letter name knowledge and first grade success. However, studies by Ohnmacht (1969), Jenkins, Bausell, and Jenkins (1972), and Samuels (1972) imply that these conclusions are based on a correlational artifact rather than a causal relationship.

Ohnmacht (1969) used three groups of first-grade students to investigate the effects of three training procedures on word discrimination and word knowledge. One group was trained on letter names, the second group was trained on letter names and letter sounds, and the third group served as a control. The group trained on letter names and sounds was superior to the other two groups in both word knowledge and word discrimination. There was no difference between the group trained in letter names and the control group.

Jenkins, Bausell, and Jenkins (1972) reported four experiments that compared the transfer value of letter name training with letter sound training. In three of these experiments, first-grade subjects received training with a set of four letter-like graphemes that bore a one-to-one grapheme-phoneme correspondence to VC words presented in a transfer task. The fourth experiment was similar to the first three except that English letters were presented instead of the letter-like graphemes. Number of trials to criterion in learning the VC words was used as the measure of transfer in all four experiments. The general conclusion of Jenkins et al. was that training with letters is effective only if it is carried out as phoneme training.

Samuels (1972) used three groups of first-grade students to investigate the assumption that letter name knowledge facilitates initial reading. One group was trained to visually discriminate among four artificial letters that resembled English letters as little as possible, the second group was also trained to discriminate among the four letters but was additionally required to learn names for the letters, the third group acted as a control and received irrelevant training. Samuels found no significant pairwise differences among the three groups in two, separate applications of the experiment. He further examined the power of the statistical tests used and concluded that a Type II (beta) error was highly unlikely.

Letter Sound and Whole Word Training

On the other hand, knowledge of letter sounds does seem to have a positive effect on word recognition in initial reading. Studies by Bishop (1964) and Jeffrey and Samuels (1967) as well as Chall's (1967) survey indicated positive transfer for letter sound training on word recognition.

Bishop (1964) simulated initial reading by teaching two groups of college freshmen and sophomores to read Arabic words and then tested the subjects' ability to learn a new list of transfer words. In learning the first list, one group received single-letter training in which letters were presented with their phonemic values, the second group received whole-word training, and the third group acted as a control. The single-letter group took significantly fewer trials to reach criterion on the transfer list than did the whole-word group, and the whole-word group did not differ significantly from the control group in trials to criterion on the transfer task. The single-letter a.d whole-word groups did not differ significantly in number of first-trial correct answers on the transfer list. Bishop speculated that this latter result may have been due to task unfamiliarity in that the single-letter subjects saw whole Arabic words for the first time in the transfer task.

Jeffrey and Samuels (1967) taught three groups of kindergarten children to read a set of monosyllabic words represented by graphemes that resembled English letters as little as possible. They then studied their subjects' ability to learn a new list of transfer words. Their procedure was essentially similar to Bishop's in that one group received single-letter training on the phonemic value of the graphemes, one group received whole-word training, and one group acted as a control. Their results corroborated Bishop's in that the letter-trained group took significantly fewer trials to reach criterion on the transfer task than did the whole-word group and that the whole-word group did not differ significantly from the control group in trials to criterion. Further, the Jeffrey and Samuels results amplified Bishop's in that the single-letter group achieved significantly more first-trial correct answers on the transfer task than did the whole-word group. Jeffrey and Samuels emphasized that letter training alone might not have produced superior transfer had it not included phonic blend training and that the graphemes used bore a one-to-one correspondence with phonemes, which is not consistently true of English orthography.

Chall's (1967) survey of methods used to teach reading included data from 17 correlational studies that examined the relationship between letter and/or phonics knowledge and reading achievement. Ten of these studies were concerned with students in the kindergarten through third-grade range. Chall concluded that

> A code emphasis--one that combines control of words on spelling regularity, some direct teaching of letter-sound correspondences, as well as the use of writing, tracing, or typing--produces better results with unselected groups of beginners than a meaning emphasis, the kind incorporated in most of the conventional basal-reading series used in schools in the late 1950's and early 1960's [p.178-179].

<u>Training Time and Transfer</u>

Samuels reported that

> Teachers who begin the teaching of reading by having the learner recognize a basic group of words as sight words have noted that at first the learning is rapid, but soon the rate of learning new words slows down drastically [1970, p. 29].

Based on this observation it seems reasonable to expect the superior transfer value of letter-sound training over whole-word training to be compromised by greater number of trials to criterion in letter-sound training. However, this was not the case in the experiments by Bishop (1964) and by Jeffrey and Samuels (1967). Bishop allotted the same amount of training to each of her three training groups, and Jeffrey and Samuels reported that their single-letter group took fewer trials to criterion than their whole-word group, although this difference was not significant.

On the other hand, Jenkins, Bausell, and Jenkins (1972) reported that training in letter-sounds took almost twice as long as training in letter-names for the set of graphemes and grapheme-phoneme correspondences taught in their experiments. Evidence is still needed to demonstrate superior transfer value for letter-sound training over letter-name training when training time is held constant. From Samuel's (1972) finding of no difference in transfer for letter-discrimination, letter-name, and control training, it seems reasonable to expect some success in any attempt to demonstrate superior transfer value for letter-sound training over letter-name training when amount of training is held constant.

Spelling Patterns

In the four reading series mentioned above, invariant grapheme-phoneme correspondences based on the association of single graphemes with single phonemes are not used. Instead, vowel-consonant (VC) combinations appear to be the basic units for these series. Use of these units seems reasonable because of the difficulty of pronouncing consonants separate from vowels. In practice, this difficulty is resolved by associating consonants with some 'neutral' vowel such as /ə/. However, it should be noted that as useful as an association between the grapheme B and the phoneme /bə/ may be in pronouncing BUT, it may be useless or even confusing in pronouncing BIT.

In *Linguistics and Reading*, Fries emphasized that the approach to initial reading recommended by Bloomfield and himself rests

> upon *the relation between the sound patterns of the words and the letter symbols of an alphabet* but this relation is *not* such as to lead us to seek to match specific letters with each of the physical 'sounds' of our language. Nor does it assume that the pronunciation of a word is a *fusion* or *blending* of the sounds represented by the individual letters by which the word is spelled [1963, p. 146].

Fries' position is that

> Modern English spelling is fundamentally a system of a comparatively few arbitrary contrastive sets of spelling-patterns, to which readers, to be efficient, must, through much practice, develop high-speed recognition responses [p. 146].

Coming from psychology rather than linguistics, Eleanor Gibson stated, on the basis of extensive empirical evidence, that

> It is my belief that the smallest component units in written English are spelling patterns. By a spelling pattern, I mean a cluster of graphemes in a given environment which has an invariant pronunciation according to the rules of English. These rules are the regularities which appear when, for instance, any vowel or consonant or cluster is shown to correspond with a given pronunciation in an initial, medial, or final position in the spelling of a word. This kind of regularity is not merely "frequency" (bigram frequency, trigram frequency, and so on), for it implies that frequency counts are relevant for establishing rules only if the right units and the right relationships are counted. The relevant graphic unit is a functional unit of one or more letters, in a given position within the word, which is in correspondence with a specified pronunciation [1970, p. 329].

The utility of spelling patterns in word recognition was reported by Gibson, Pick, Osser, and Hammond (1962) who discussed two investigations of the role of spelling patterns in word perception. In both experiments, performance on pseudo-words conforming to English rules of spelling to sound correspondence was compared with performance on pseudo-words that were matched for summed letter frequency but that did not conform to English rules of spelling to sound correspondence. The pseudo-words were presented by tachistoscope to college students. In the first experiment, subjects were required to write down words as they appeared on a screen. The results indicated significantly superior performance by the subjects on the pseudo-words that conformed to English spelling rules. The authors concluded from the first experiment that

> The proper unit for analyzing the process of reading (and writing) is not the alphabetical letter but the spelling pattern which has an invariant relationship with a phonemic pattern [p. 564].

The second experiment required subjects to identify a tachistoscopically presented target from among a field of four words. Results and conclusions from the second experiment corroborated those of the first, and enabled Gibson et al. to conclude that their results were not simply due to a bias to emit pronounceable responses but that the perception of the target was genuinely affected by its conformity to the spelling rules of English.

In initial reading, the use of spelling patterns encounters several practical difficulties, one of which is the strained vocabulary that results in choosing words to illustrate the regular spelling patterns being presented, and another of which is the pronunciation of an orthographically regular utterance in ordinary discourse. Both of these difficulties are illustrated by Bloomfield's prototypal "NAN CAN FAN DAN." The sentence appears strained because Nan is not a particularly familiar name and because who can fan whom is not a concern of moment to initial readers. Further, the sentence may contain grapheme-phoneme irregularities in ordinary discourse. For instance, CAN in this sentence would be ordinarily pronounced /ken/ or /kɪn/ in American dialects.

More serious, however, are the irregularities that occur even when spelling patterns are considered separate from ordinary speech. A student who has learned to associate /:t/ with -UT will presumably be more likely to recognize CUT, HUT, JUT, etc. However, he may experience difficulty with PUT. As long as phonemic correspondences to graphemes are used, large numbers of exceptions will be encountered.

On the other hand, English orthography may be more closely rule-governed than the number of exceptions to regular grapheme-phoneme correspondences indicate. This possibility is indicated in extensive empirical studies of English orthography by Hanna, Hanna, Hodges, and Rudorf (1966), Venezky (1967), (1970), and Berdiansky, Cronnell, and Koehler (1969) and in the generative English phonology of Chomsky and Halle (1968) who introduce the concept of lexical representation.

Lexical Representation

Grapheme-phoneme correspondences may be only peripheral to the more basic and direct relation of letters to segments in lexical representation. The utility of emphasizing spelling-sound correspondences in teaching initial reading seems well-founded by Bloomfield and Fries and by the empirical investigations of Gibson, Samuels, and Williams among many others. It may be, however, that those who seek grapheme-phoneme correspondences are off the mark. Williams makes this point directly in discussing the work of Venezky and Weir (1966) "who demonstrated that there is considerable regularity between English orthography and oral language if one looks beyond the direct grapheme-phoneme relationship [1971, p. 7-155]." Also Gillooly, again discussing Venezky's (1967) work, states that

> scholars have begun to seek an underlying regularity in traditional English orthography beyond the level of grapheme-phoneme correspondences, a regularity that is mediated, or indirect. And, their search has been rewarding. As a result of such activity, it can be stated that because our English writing system is deficient as a phonetic (or phonemic) transcription of the spoken language, it does not follow that it is a poor, or an irregular one [1971, p. 7-26].

In their discussion of English sound structure Chomsky and Halle state that

> The surface structure that enters the phonological component is determined by three factors: syntactic rules, lexical representations, and readjustment rules. The syntactic rules generate a syntactic surface structure of strings of grammatical and lexical formatives, the latter appearing in what we have called "lexical representation." The readjustment rules, which provide a link between syntax and phonology, may slightly modify the syntactically generated surface structure, and they will, furthermore convert the string of formatives into what we have called "phonological representation," introducing various modifications into the lexical representations and eliminating grammatical formatives in favor of phonological matrices [1968, p. 163].

Lexical representations are therefore distinct from phonological representations even though the two representations are related to one another by rules. The term 'lexical representation' refers "to formatives which are provided directly by the lexicon, i.e., the lexical formatives as well as certain grammatical formatives which happen to appear in lexical entries [Chomsky & Halle, 1968, p. 9]."

Chomsky amplified his discussion of lexical representation for the Project Literary papers edited by Levin and Williams (1970). In discussing Chomsky's paper, Francis listed three distinct parts to Chomsky's claim:

> (1) that the prephonetic level of surface structure, the level of lexical representation, is linguistically meaningful; (2) that this level and the lexical representations that it includes are psychologically real, though below the level of conscious knowledge; and (3) that the standard orthography is, with minor exceptions, isomorphic with that level [1970, p. 48].

As Francis indicated, Chomsky's claims that "the psychological reality of lexical representation, in this sense, is hardly open to question [1970, p. 7]" and that conventional orthography in English and in other languages is a near optimal transcription for spoken language (1970, p. 4) are obvious overstatements, but these exaggerations should not weaken the basic argument.

The arguments for lexical representation do not necessarily impugn the utility of spelling patterns as basic units for transfer in initial reading. Phonemic representations may be irrelevant to linguistic theory as Chomsky and Halle (1968) suggest, but the relation of English orthography to lexical representation is neither well established nor well defined. We can no longer speak confidently of grapheme-phoneme correspondences with respect to linguistic theory, but for teaching initial reading these correspondences remain the best defined and best understood fundamental units of transfer.

In cuing on grapheme-phoneme correspondences in teaching initial reading, we can expect irregularities and exceptions to occur. Further, if we assume that students have internalized English sound system rules relating lexical to phonological representations, an emphasis on grapheme-phoneme correspondences may only hint at the rules relating orthography to more abstract levels of language that students must discover in order to read. Spelling patterns must be understood not simply as indicators of an independent system of grapheme-phoneme correspondences, but as indicators of the more fundamental rules that are used to relate orthography to meaning in the reading process.

SPELLING PATTERNS AND TRANSFER

Transfer is a natural aim for instruction, which could achieve little if it were limited to material that could be taught only directly. More is to be gained if a few things can be taught from which many things can be learned, and transfer is the obvious motivation for emphasizing spelling patterns in initial reading. It seems reasonable to conclude that positive transfer has occurred as a function of having taught spelling patterns if subjects are better able to read unfamiliar items that include the patterns taught. This procedure was used to obtain measurable evidence that positive transfer occurred in the present study as well as in the investigations by Bishop (1964), Jeffrey and Samuels (1967), and Jenkins, Bausell, and Jenkins (1972).

Four experimental training treatments were used in this investigation. These treatments differed from one another in the way they presented spelling patterns to students using the Stanford computer-assisted instruction (CAI) program in initial reading. These training treatments could have been presented in classrooms by trained experimenters, but the precise and unobtrusive control over treatment conditions possible under CAI made the computer-assisted reading program the most attractive medium for presenting them. This investigation, then, owes much in terms of experimental control to the Stanford CAI program. However, the results and conclusions of this investigation are independent of CAI; they should be applicable to any program in initial reading.

The Stanford CAI Program in Initial Reading

The advent of sophisticated computational techniques such as time-sharing and digitized, multiplexed audio permitted development of CAI in initial reading. The Institute for Mathematical Studies in the Social Sciences (IMSSS) has supported CAI in initial reading since 1964. Early efforts by IMSSS were successful and have been documented by Atkinson and Hansen (1966), Atkinson (1968), and Wilson and Atkinson (1968).

The version of the CAI program used in this investigation was described by Atkinson and Fletcher (1972). Student terminals were 'KSR Model 33' teletypewriters equipped with earphones over which digitized, randomly accessed audio information was played. An assessment of this version was reported by Fletcher and Atkinson (1972), and the current version of the program was described by Atkinson, Fletcher, Campbell, Lindsay, and Barr (1973).

Decoding by means of spelling patterns receives a major emphasis in the Stanford CAI program in initial reading. However, decoding is not the sole concern of the program. The version used for this investigation divided instruction into seven content areas or strands. Strand 0, the readiness strand, provided practice with the manual skills required for interaction with the CAI program, Strand I, the letter strand, provided practice in copying, recognition, and recall of the letters of the alphabet. The initial pass through the alphabet presented letters singly and in maximally contrasting groups, for example (RTO); later passes through the alphabet presented letters in minimally contrasting groups, for example (MNW). Strand II, the word strand, provided for the development of a sight word vocabulary. Seven K through 3 reading vocabulary lists were analyzed in developing this strand. Of the words used in Strands II through IV, those that did not include regular grapheme-phoneme correspondences were presented only in this strand. Strand III, the spelling strand, provided for recognition and recall of monosyllabic words arranged in groups that emphasized a single spelling pattern (RAN, FAN, MAN or FAT, FAN, FAD). Strand IV, the phonics strand, provided direct practice in copying and recognition of the spelling patterns themselves as well as 'construction' of monosyllabic words from given consonant clusters and spelling patterns. Strand V, the comprehension categories strand, provided practice with the meaning of words by emphasizing their semantic categories. Exercises in this strand asked the student to select the word of those displayed that was an animal or that was a color, etc. Strand VI, the comprehension sentence strand, provided practice in reading sentences by requiring the student to select a word to fill an empty "slot" in the sentence. On any given day, a student's lessons could include exercises drawn from one to five different strands.

The Stanford CAI curriculum is unique among spelling pattern curriculums in two respects. First, other curriculums present spelling patterns implicitly; spelling patterns that are not themselves words (-AB) are presented only as components of words (CAB, TAB, SLAB); they are never presented explicitly by themselves. The Stanford CAI program presents spelling patterns both implicitly in the spelling strand and explicitly in the phonics strand. Second, the spelling patterns chosen for other curriculums are usually final consonant (FC), or final unit, patterns; they are syllable endings (-AB -AN -AT) rather than syllable beginnings (BA- NA- TA-). The Stanford CAI curriculum presents both FC and initial consonant (IC), or initial unit, spelling patterns.

The three phonics strand exercises presented the four training treatments considered by this investigation. These three exercises were the following:

Exercise 1 (copying)--the program printed a spelling pattern (-AN), the audio played a response request ("type an as in can") and the student was expected to type the displayed pattern (AN or -AN);

Exercise 2 (recognition)--the program printed the target spelling pattern and two distractors in random order (-AB -AN -AT), the audio played a response request ("type an as in began"), and the student was expected to select and type the target spelling pattern (AN or -AN);

Exercise 3 (build-a-word)--the program printed the target spelling pattern and two distractors in random order (-AN -AB -AT), additionally it printed a consonant or consonant cluster (ST--), the audio played the response request ("type Stan"), and the student was expected to type the requested word (STAN).

The exemplars in exercises 1 and 2 were chosen at random from a set of one polysyllabic and two monosyllabic words for each spelling pattern that illustrated use of the pattern (BEGAN CAN STAN). In exercise 3 the target word was chosen from the two monosyllabic exemplars (CAN STAN). The specific goal of the phonics strand was to enable students to pronounce (to read) any regular grapheme comprised of spelling patterns taught in the curriculum. This objective seems implicit in any initial reading curriculum that emphasizes spelling patterns.

Overview of the Present Investigation

The absence of IC units in spelling pattern curriculums indicates a consensus against their value as basic units transfer in initial reading. Superficially, this consensus appears unfounded. There is no obvious reason why training that associates MA with /mae/ should be any more or less useful to a student who must recognize, or read, MAT than training that associates AT with /æt/. However, we need to consider what rules might relate the orthography of MAT, MATE, MAR, MARE to their phonetic representations. Knowing the final units in these cases provides more relevant information than knowing the initial units. A student who is trained with final units may have an advantage over a student who is trained with initial units, because final unit training provides more of the information needed to pronounce the target grapheme. On the other hand, in pronouncing, or reading, the target grapheme, the student must reproduce the phonetic representation of the target from left to right, and training with initial units should be more useful in a pronunciation task.

In any case, an empirical investigation of the relative utility of IC and FC unit training is of interest from both practical and theoretical standpoints. Data-based decisions need to be made about IC units in spelling pattern curriculums, and results that indicate a superior transfer value for either IC or FC unit training will have implications for the 'psychological reality' of rules that relate English orthography to meaning.

Four experimental training treatments are suggested by these considerations, and these four treatments were used in this investigation:

(1) 'B' -- practice with both initial and final units of target graphemes;

(2) 'I' -- practice only with initial units of target graphemes;

(3) 'F' -- practice only with final units of target graphemes;

(4) 'N' -- practice with neither initial nor final units of target graphemes.

The relative utility of these four training treatments was measured by the ability of subjects to pronounce, or read, criterion task items made up of the spelling patterns taught. The investigation was limited to single-vowel, monosyllabic targets. Each subject received training on half of the set of spelling patterns to which he was assigned, but the items he received in the criterion task comprised all possible combinations of all the IC and FC units in the set.

Also of interest in the investigation were effects due to the configuration of target items, the meaningfulness of target items, the vowel-phoneme association in target items, and the sex of the subjects. Four configurations in the target monosyllables were considered: CVC, CCVC, CVCC, CCVCC. Presumably, the presence of consonant clusters may affect the difficulty of reading a target monosyllable. Hansen and Rodgers (1968) taught 20 eight-year old children 12 nonsense syllables. Two of these syllables were of the configuration CCCVC, two were CVCCC's, two were CCVCC's, and six were disyllabic CVCVC's. The authors do not report planned or post-hoc comparisons using the CCVCC's, but they do report that the CVCCC's were significantly more difficult than the CCCVC's and the CVCVC's. On the basis of these inferential data and other descriptive data from the Hansen and Rodgers study, it seems reasonable in the present investigation to expect an ordering from easiest to most difficult configuration of CVC, CCVC, CVCC, CCVCC.

Words as targets should be easier for the subjects than non-words. However, this effect was expected to be less noticeable under the B treatment than under the N treatment because training external to the experimental treatments should have a greater effect on target graphemes under the N treatment.

The specific grapheme-phoneme associations required by the vowel-phonemes in the target graphemes was not expected to affect item difficulty. However, any indication of such an effect would be of interest.

Superior performance by girls in initial reading has long been noted; this literature was reviewed by McNeil (1964) and Maccoby (1966) among others. However, Atkinson (1968) and Fletcher and Atkinson (1972) reported an absence of superior performance by girls in the Stanford CAI program, and Jeffrey and Samuels (1967) also reported a similar absence of the effect in their study of phonics based initial reading instruction.

Performance in initial reading decoding tasks may be independent of sex, and this effect, or lack of it, is of interest in the present study.

Within subjects, or repeated measures, designs were used to investigate the effects of the four training treatments, the four configurations, and the word and non-word criterion task items. Between subjects designs were used to investigate the effects of the vowel-phonemes and the sex of the subjects.

PROCEDURE

Subjects

From its inception, the CAI reading program has been provided in a school in a predominantly Black, economically depressed neighborhood. Within this school, 72 subjects, 25 boys and 47 girls, from three, moderate-ability first grade classes were chosen for this investigation. Beginning in the fall of the school year, students in these classes received 8-minute CAI reading sessions as an integral portion of their daily activity. Students chosen as subjects for this experiment had accumulated 6 minutes of session time within the phonics strand before beginning the experiment. All subjects, therefore, were familiar with the CAI reading program and with the exercise formats of the phonics strand. The experiment was run in May as part of the subjects' daily CAI sessions.

Materials

One set of 24 spelling patterns was devised for each of the five vowels: A, E, I, O, and U. These five sets of spelling patterns were constructed under the following constraints.

(1) Of the 24 patterns in each set, 6 were to be IC units of the form CV-, 6 were to be IC units of the form CCV-, 6 were to be FC units of the form -VC, and 6 were to be FC units of the form -VCC. There were, therefore, (12 × 12) 144 combinations of IC and FC units for each vowel.

(2) The number of words in the 144 possible combinations of all IC units with all FC units in each set was to be maximized. A 'word' was operationally defined as an entry in Webster's New World Dictionary (1966) not marked as obsolete or poetic (RATH and PROG were among the resulting IC-FC combinations), archaic (HATH and HAST were among the combinations), slang (LAM, STASH), dialectical (PASH, MUMP), as an abbreviation (DIST, MIN), or as an interjection (HIST). Proper names (PAM, DICK, TED) and entries marked as colloquial (MATH, MOM) were classified as words. Some recognizable IC-FC combinations (CHIMP, FLAB) were not classifiable as words under this definition, and some very unusual combinations (FID, NEB) were. The aim of the grapheme-phoneme correspondence technique emphasized in this investigation is to enable students to pronounce arbitrary orthographic combinations so that they can associate prior semantic and syntactic knowledge with what they hear. Therefore, the most appropriate definition of 'word' for this investigation is any phonemic unit with which subjects have prior semantic and syntactic experience, i.e., any element in the subjects' recognition, or listenting, vocabulary. The entries in Webster's New World Dictionary were assumed to be as good an approximation of first graders' recognition vocabularies as any other readily available set of items, particularly with respect to items of the limited configurations (CVC, CCVC, CVCC, CCVCC) used in this investigation. The number of word and non-word

items under each vowel, each configuration, and each vowel by configuration 'cell' that resulted from the operational definition of 'word' are shown in Table 1. All IC-FC combinations and their classification as words or non-words are listed in Appendix A.

(3) Obvious obscenities resulting from the combination of IC and FC units were to be avoided.

(4) Each IC-FC combination that resulted in a word was to be ordinarily pronounced with the same vowel-phoneme that was associated with the separate IC and FC units during the experiment training period. For example, -ON was presented as an FC unit associated with the phoneme /an/, and, although initial units such as RO- and PO- could be used, TO- could not be presented as an IC unit associated with the phoneme /ta/ because the IC-FC combination, TON, is ordinarily pronounced as /tən/.

(5) There had to be one monosyllabic and one polysyllabic word that could exemplify each spelling pattern in the instructional portion of the experiment. The monosyllabic exemplar could not be one of the IC-FC combinations derived from the spelling patterns presented in the experiment. The exemplars for each spelling pattern in the experiment are given in Appendix B.

The spelling patterns taught in the experiment are listed by vowel in Table 2. The vowel A was associated with the phoneme /æ/, E was associated with /e/, I with /I/, O with /a/, and U with /ə/.

Generally, the notation, CC, refers to two consonant letters associated with two consonant phonemes. However, three units for A (-ACK -ATH -ASH), two units for E (CHE- -ECK), two units for I (CHI- -ICK), five

Table 1

Number of Word and Non-word Criterion Task Items

Classified by Vowel and Configuration

		CVC	CCVC	CVCC	CCVCC	Total
A	words	25	20	23	13	81
	non-words	11	16	13	13	63
E	words	14	4	16	8	42
	non-words	22	32	20	28	102
I	words	22	17	19	5	63
	non-words	14	19	17	31	81
O	words	22	8	12	8	50
	non-words	14	28	24	28	94
U	words	20	4	26	12	62
	non-words	16	32	10	24	82
Total	words	103	53	96	46	298
	non-words	77	127	84	134	422

Table 2

Spelling Patterns Taught in the Experiment

Vowel: A = /æ/			
CA-	CLA-	-AD	-AND
LA-	GRA-	-AG	-AST
RA-	SLA-	-AM	-ACK
PA-	CRA-	-AN	-ATH
MA-	FLA-	-AB	-AMP
HA-	STA-	-AT	-ASH
Vowel: E = /e/			
BE-	CHE-	-ET	-END
NE-	FRE-	-EB	-ECK
SE-	PRE-	-EM	-ELT
FE-	SWE-	-EN	-ENT
TE-	DRE-	-EP	-EST
LE-	SPE-	-ED	-ELD
Vowel: I = /ɨ/			
FI-	CHI-	-ID	-ILT
HI-	TWI-	-IP	-ICK
LI-	SPI-	-IM	-ISK
MI-	DRI-	-IN	-IST
SI-	TRI-	-IT	-INT
DI-	SKI-	-IG	-IMP
Vowel: O = /a/			
LO-	CRO-	-OD	-OCK
HO-	FLO-	-OT	-OND
CO-	SHO-	-OM	-OFT
RO-	CLO-	-ON	-ONG
PO-	PRO-	-OB	-OSH
MO-	STO-	-OG	-OTH
Vowel: U = /ə/			
BU-	CRU-	-UD	-UNG
SU-	DRU-	-UP	-UCK
HU-	SKU-	-UM	-UMP
LU-	GRU-	-UG	-UNT
MU-	TRU-	-UN	-UST
RU-	PLU-	-UT	-UNK

units for O (SHO- -OCK -ONG -OSH -OTH), and two units for U (-UNG -UCK) required the association of two consonant letters with a single phoneme.

Method

When each subject began the experiment, he was randomly assigned to one of the five sets of spelling patterns and then 12 of the 24 spelling patterns in the chosen set were selected for training. The number of subjects trained on each of the five sets of spelling patterns is shown in Table 3.

It should be noted that all randomization required by this investigation used a standard algorithm for generating random numbers. Van Gelder (1967) describes this algorithm in his discussion of power residue pseudo-random number generators.

Selection of the 12 spelling patterns for each subject's training was stratified so that 3 of the patterns were IC units of the configuration CV-, 3 were IC units of the configuration CCV-, 3 were FC units of the configuration -VC, and 3 were FC units of the configuration -VCC. This stratification, then, yielded four sets of 3 patterns each and within subjects designs for investigating the effects of training treatment, configuration, and meaningfulness. In the training portion of the experiment, each subject received two consecutive days of practice with each of the four sets of three spelling patterns that were assigned to him, yielding a training period of eight days. The order in which the four sets of spelling patterns were presented was randomized for each subject.

Practice consisted of a fixed number of trials in the phonics strand exercises according to the following schedule:

Table 3

Number of Subjects Assigned to Each of the

Five Sets of Spelling Patterns

	A	E	I	O	U	Total
Boys	4	5	5	5	6	25
Girls	9	10	10	7	11	47
Total	13	15	15	12	17	72

Day 1

3 trials--exercise 1 (copy)

4 trials--exercise 2 (recognition)

3 trials--exercise 3 (build-a-word)

Day 2

2 trials--exercise 1 (copy)

4 trials--exercise 2 (recognition)

4 trials--exercise 3 (build-a-word)

A 'trial' consisted of one presentation of each of the three spelling patterns. Therefore, on each of the two consecutive days, a subject received ten presentations of each spelling pattern or a total of 20 presentations for each spelling pattern assigned to him. Because of a warm-up effect apparent in CAI performance data (cf. Wilson and Atkinson, 1968) subjects ran for two minutes in their ordinary day's session exclusive of the phonics strand before being branched into the experimental treatment. Subjects were signed off when they completed the 30 presentations in the day's experimental treatment. CAI sessions for the subjects were slightly more variable in length than normal student sessions. Sessions for subjects in the training portion of the experiment lasted 7-9 minutes compared with the more precisely timed 8-minute sessions of non-experimental students. The experimental training portion of these sessions lasted 5-7 minutes.

At the end of his eight-day training period, each subject was individually tested, off-line, on all 144 IC-FC combinations derived from the full set of 24 spelling patterns to which he was assigned. In administering the test, each item, printed in upper case primary type on an unlined 3 × 5 index card, was shown to the subject who then had 10 seconds to read the word aloud. All the tests were administered by one of three people who knew to which set of spelling patterns subjects had been assigned but who did not know with which 12 patterns each subject was trained. The order for presenting each set of 144 IC-FC combinations was randomized for that set. Each test took 15-25 minutes to administer.

Subject's entry into the training portion of the experiment was 'staggered' so that subjects would finish the training and become ready for testing on different days. An attempt was made to test each subject on the day following his completion of the 8-day training period. This attempt was generally successful, but delays of four days occurred in two instances and eight subjects were tested on the same day that they finished the training period.

Because each subject was trained on 6 of the 12 IC units and 6 of the 12 FC units to which he was assigned, (6 × 6) 36 of the 144 IC-FC combinations on which he was tested fell under the B training treatment (training on both IC and FC unit). Similarly, another 36 of the 144 test items fell under the I training treatment (training on IC unit only), 36 fell under the F treatment (training on FC unit only), and 36 fell under the N treatment (training on neither IC nor FC unit). Further, because each subject was trained with 3 IC units of the CV- configuration and 3 FC units of the -VC configuration, 9 of the 36 test items falling under the B treatment were CVC's. Similarly, 9 of the 36 B items were CCVC's, 9 were CVCC's, and 9 were CCVCC's. In other words, each subject received 36 items under each of the four training treatment conditions (B, I, F, or N), 36 items under each of the four configurations (CVC, CCVC, CVCC, and CCVCC), or 9 items in each of the (4 × 4) 16 treatment by configuration 'cells' (B & CVC, B & CCVC, ..., I & CVC, ..., N & CCVCC).

RESULTS

Table 1 presented earlier shows that the numbers of words and non-words under the different vowels and the different configurations varied significantly. There were almost twice as many words under the vowel A as under E, and there were over twice as many words under the CVC configuration as under CCVCC. That words were significantly easier for subjects than non-words is supported by data presented later in this paper. Therefore, an investigation of the relative difficulties of the vowels and configurations in the study is likely to be confounded by the differing proportions of words and non-words if it uses the number of correct answers under each vowel and configuration category as the measure of interest.

Because of the varying proportions of words and non-words, analyses of the vowel, treatment, and configuration effects were made separately, and parallel analyses for words and non-words were performed in investigating vowel and configuration effects. When separate analyses were performed for words and non-words, the data were first transformed to proportions, and statistical inferences were drawn using non-parametric techniques. Under these circumstances the transformation to proportions was necessary because, as we might expect, the number of total correct answers possible varied widely between subjects. The difficulties in using proportions in parametric tests of statistical inference are legion, and non-parametric statistical inference was used when the data under consideration were proportions.

Training Treatment

The relative effects of the four training conditions--B (training on both IC and FC units), I (training on IC units only), F (training on FC units only), and N (training on neither IC nor FC units)--were of primary interest for this investigation. Means and standard deviations of correct answers over all 72 subjects are reported in Table 4 for the four training conditions. Table 4 also summarizes the results of a single-factor analysis of variance for repeated measures (Winer, 1971) used to investigate the training treatment effect. The F-ratio for this analysis was significant at $p < .01$, and post-hoc pairwise comparisons of the average number of correct answers made under the four treatments were undertaken using the Tukey 'honestly significant difference' (hsd) procedure discussed by Winer. This procedure uses Tukey's studentized range as does the more common Newman-Keuls procedure but, instead of adjusting the critical value depending on the dispersion of the two values, it uses the critical value for the maximum dispersion possible among all possible pairwise comparisons. Despite the conservatism of the hsd procedure, an answer for the major experimental question underlying this investigation is indicated by the data. As Table 5 shows, both the B and F procedures were superior to both the I and N procedures, there was no significant difference between the B and F procedures, and there was no significant difference between the I and N procedures. In other words, over all subjects and all items, the F procedure was about as good as the B procedure, and the I procedure was about as poor as the N procedure in training subjects for the test.

Table 4

Analysis of Variance for the Four Training Treatments

Training	B	I	F	N
Sample size	72	72	72	72
Mean correct	23.58	21.03	22.78	20.18
Standard deviation	10.14	10.56	10.22	10.67

Analysis of Variance

	Sum of squares	df	Mean square	F
Between subjects	29533.91	71		
Within subjects	1705.75	216		
Training	527.12	3	175.51	31.75**
Residual	1178.63	213	5.53	
Total	31239.66	287		

**Significant, $p < .01$; $F_{.99}(3,213) = 3.88$

Table 5

Post-hoc Pairwise Comparisons for Average Correct Answers under the Four Training Treatments

Training		N	I	F	B
	Mean correct	20.18	21.03	22.78	23.58
N	20.18	---	.85	2.60**	3.40**
I	21.03		---	1.75**	2.55**
F	22.78			---	.80
B	23.58				---

**Significant, $p < .01$; $q_{.99}(4,213)\ \sqrt{MS(residuals)/n} = 1.25$

Configuration

Teachers of reading have long noted that items with consonant clusters or blends are more difficult for students to read than are items with single consonants, and, in the current data, CVC's should be easier for students than CCVCC's. The relative difficulties of CCVC's and CVCC's are not so intuitively obvious. Examination of the configuration effect in the current data could be confounded by the different proportions of words and non-words within items of the same configuration, and, for this reason, separate analyses for configuration effect were performed for words and non-words.

Because the spelling patterns for each subject's training were selected at random, the number of word and non-word items under each configuration category differed from subject to subject. Therefore, the number of correct answers each subject achieved under each configuration category was transformed to a proportion. These proportions were then ranked for each subject under the four configuration categories. For each subject, '1' was assigned to the category with the greatest proportion of correct answers, '2' to the category with the next greatest proportion of correct answers, '3' to the next, and '4' to the category with the smallest proportion of correct answers.

There was a significant number of tied proportions in these data; 20 subjects had at least one pair of tied proportions in the word items and 9 subjects had at least one pair of tied proportions in the non-word items. The problem of assigning ranks to these data was resolved by discarding subjects with at least one pair of tied observations, leaving 52 subjects for the word items and 63 subjects for the non-word items.

This procedure for resolving ties is recommended by Bradley (1968) when it is reasonable to assume that there is no relevant bias in the discarding process. This method yields probability statements that are exactly true for the unambiguous (untied) part of the sample, but it only estimates the exact probability levels for the entire sample. Naturally, the reduction in sample size reduces the power of the test, but this reduction is less than that suffered under other methods discussed by Bradley.

Means and standard deviations of the ranks for each of the four configuration categories are given for word items in Table 6 and for non-word items in Table 7. There are six pairwise comparisons in both sets of data, and these comparisons are also presented in Tables 6 and 7 for word and non-word items, respectively. These comparisons are based on an hsd procedure that uses Tukey's studentized range statistic and is discussed by Miller (1966). This procedure uses the Friedman statistic for comparing ranks and derives a simultaneous test for large n from the following statistic:

$$|\overline{R}_i - \overline{R}_j| \leq q_{\alpha(k,(n-1)(k-1))} \left[\frac{(k)(k+1)}{12n}\right]^{1/2} \qquad i,j = 1,\ldots,k$$

with probability approximately $1-\alpha$. $\overline{R}_i$ and $\overline{R}_j$ are the mean ranks under treatments i and j, and, in all, there are n observations matched and ranked under the k treatments. The null hypothesis that there is no treatment effect is accepted when all the mean rank differences, $|\overline{R}_i - \overline{R}_j|$, fail to exceed the critical constant. Any difference that exceeds the critical constant for some $\overline{R}_i$ and $\overline{R}_j$ is taken to indicate a population difference.

Table 6

Pairwise Comparisons for the Four Configurations of Word Items

Configurations	CVC	CCVC	CVCC	CCVCC
Sample size	52	52	52	52
Mean rank[a]	2.00	2.90	1.96	3.13
Standard deviation	1.01	1.11	.91	.95

Configurations	Mean rank	CVCC 1.96	CVC 2.00	CCVC 2.90	CCVCC 3.13
CVCC	1.96	---	.04	.94**	1.17**
CVC	2.00		---	.90**	1.13**
CCVC	2.90			---	.23
CCVCC	3.13				---

**Significant, $p < .01$; $q_{.99}(4,153)\left[\frac{(k)(k+1)}{12n}\right]^{1/2} = .81$

[a]Rank 1 was assigned to the configuration with the largest proportion of correct answers, rank 2 to the configuration with next largest, etc.

Table 7

Pairwise Comparisons of the Four Configurations of Non-word Items

Configurations	CVC	CCVC	CVCC	CCVCC
Sample size	63	63	63	63
Mean rank[a]	1.97	2.83	2.08	3.13
Standard deviation	.95	1.06	1.02	1.02

Configurations		CVC	CVCC	CCVC	CCVCC
	Mean rank	1.97	2.08	2.83	3.13
CVC	1.97	---	.11	.86**	1.16**
CVCC	2.08		---	.75**	1.05**
CCVC	2.83			---	.30
CCVCC	3.13				---

**Significant, $p < .01$; $q_{.99}(4,186)\left[\frac{k(k+1)}{12n}\right]^{1/2} = .73$

[a]Rank 1 was assigned to the configuration with the largest proportion of correct answers, rank 2 to the configuration with the next largest, etc.

The comparisons in Tables 6 and 7 indicate similar results for the configuration effect among word and non-word items, respectively. Over all treatments, CVC's and CVCC's were significantly easier than CCVC's and CCVCC's and there were no significant differences between CVC's and CVCC's or between CCVC's and CCVCC's. In other words, CVC's were about as easy as CVCC's, and CCVC's were about as difficult as CCVCC's.

It is reasonable to expect an interaction between configuration and training treatment. Even though over all treatments, CVCC's were significantly easier than CCVC's for both word and non-word items, training on initial units only should reverse this effect, and, specifically, CCVC's should be easier for subjects than CVCC's under the I training treatment. To investigate the possibility of this interaction, sign tests were used to compare proportions of CCVC's and CVCC's correct under the I treatment for both word and non-word items. As in the pairwise comparisons with ranks, subjects with tied observations were discarded, yielding 53 subjects for the word items and 54 subjects for the non-word items. The normal approximation to the binomial distribution was used to compute Z-values for these sign statistics following a procedure outlined by Siegel (1956) and assuming $p = q = 1/2$. The results of these two sign tests are shown in Table 8. The sign test for words indicated no significant difference between CCVC's and CVCC's, and the sign test for non-words indicated that under the I training treatment CCVC's were significantly easier than CVCC's at $p < .01$. The latter was the expected result. The results of the analysis for word items may have been due to the subjects' prior familiarity with the words used.

Table 8

Sign Tests for Relative Proportions of Correct Word and Non-word CCVC's and CVCC's

Among word items:	
P(CCVC) < P(CVCC)	= 28
P(CCVC) > P(CVCC)	= 25
P(CCVC) = P(CVCC)	= 19
Z-value	= .275
Among non-word items:	
P(CCVC) < P(CVCC)	= 16
P(CCVC) > P(CVCC)	= 38
P(CCVC) = P(CVCC)	= 18
Z-value	= -2.858**

**Significant, $p < .01$; $Z_{.99} = 2.576$.

Words and Non-words

Apart from any treatment effect, the number of correct answers given to an item should depend on whether it is a word or non-word. Four sign tests, one for each of the training treatments, were performed to investigate this effect. These tests compared, for each subject, the proportion of correct word items with the proportion of correct non-word items after responses under all four configurations were summed. Again following Bradley's recommendation, subjects with tied observations were discarded. These four analyses are summarized in Table 9. As expected, all four tests indicated significantly greater proportions of correct word items than of non-word items at $p < .01$. It can be noted from Table 9 that there were 19 subjects who made proportionally more correct responses to non-word items than to word items under the N training treatment. Evidently, subjects were able to draw on training external to that given in this investigation.

Additionally, it might be argued that there should be a treatment effect on the relative proportions of correct words and non-words. Because both IC and FC units are practiced under the B treatment, the word-non-word effect may be relatively less than under the N treatment where, presumably, the subjects had prior experience only with a few of the word items. Cochran's 'Q' test for a single factor, repeated measures, and dichotomous data was used to investigate this possibility. The 'Q' statistic is distributed approximately as chi-square with k-1 degrees of freedom when there are k treatments and the number of subjects is relatively large (Winer, 1971). In the current data, the proportion of correct words was compared with the proportion of correct non-words

Table 9

Sign Tests for Relative Proportions of Correct Words and Non-words under the Four Training Treatments

Under the B treatment:	
P(correct words) < P(correct non-words) =	10
P(correct words) > P(correct non-words) =	57
P(correct words) = P(correct non-words) =	5
Z-value = -5.620**	
Under the I treatment:	
P(correct words) < P(correct non-words) =	14
P(correct words) > P(correct non-words) =	55
P(correct words) = P(correct non-words) =	3
Z-value = -4.815**	
Under the F treatment:	
P(correct words) < P(correct non-words) =	16
P(correct words) > P(correct non-words) =	53
P(correct words) = P(correct non-words) =	3
Z-value = -4.334**	
Under the N treatment:	
P(correct words) < P(correct non-words) =	19
P(correct words) > P(correct non-words) =	51
P(correct words) = P(correct non-words) =	2
Z-value = -3.705**	

**Significant, $p < .01$; $Z_{.99} = 2.576$.

for each subject by treatment combination. If the proportion of correct words was greater, the observation was recorded as a 1; if the proportion of correct non-words was greater, the observation was recorded as 0; if the proportions under any treatment were tied for a subject, that subject was discarded. This analysis for 64 subjects is summarized in Table 10. The resulting 'Q' statistic was not significantly different from zero, and these data do not indicate a training treatment effect on the relative proportions of correct words and non-words.

Vowel-Phoneme

The possibility of a vowel-phoneme effect was of peripheral interest in this study. The vowel-phoneme associations presented were not expected to affect item difficulty, but the implications of such an effect, if found, were sufficiently intriguing to warrant some investigation.

Table 3 shows the number of subjects trained on each of the five sets of spelling patterns, and the number of words and non-words under each vowel are shown in Table 1. In investigating the vowel-phoneme effect, words and non-words were kept separate, and Kruskal-Wallis multi-sample rank tests were performed for the two sets of data. In ranking proportions for these tests, subjects with tied observations were not discarded. Using the procedure discussed by Siegel, mean ranks were assigned to tied observations, and the 'H-value' for the Kruskal-Wallis test was corrected for the number of ties that occurred. This procedure is justified by Kruskal and Wallis themselves (1952), and seems warranted in the specific instance of calculating the H-value despite Bradley's strong but general cautions against using mean ranks.

Table 10

Cochran's Q Test for Relative Proportions of Correct Words and Non-words under the Four Training Treatments

Treatment	B	I	F	N
Sample size	64	64	64	64
Sum	55	50	48	46

Mean over all sums = 49.75

Q-value = 4.296*

*Not significant; $\chi^2_{.95}(3) = 7.81$.

The primary difficulty with the Kruskal-Wallis rank procedure is discussed by Miller who points out that the outcome of any pairwise comparison depends on all the populations under consideration; the same set of observations from two populations can differ significantly in one experiment but not in another. For this reason, Miller recommends the Steel-Dwass multi-sample rank procedures over the Kruskal-Wallis procedures. ever, the Steel-Dwass procedures do not permit unequal numbers of observations in the population samples, and the Kruskal-Wallis procedure was therefore used in this investigation.

The two Kruskal-Wallis tests for vowel-phoneme effect are summarized in Table 11. For relatively large numbers of observations, *H-values* are distributed approximately as chi-square with k-1 degrees of freedom for k treatments. Neither test indicated a significant effect on item difficulty due to the vowel-phoneme associations.

Sex

The possibility that girls may out-perform boys is always of interest in tasks related to initial reading, and it is of particular interest in reading CAI. Means and standard deviations for correct answers achieved by the 25 boys and 47 girls in this study are shown for each of the four training treatment groups in Table 12. The table also gives *t-values* for the differences between boys' and girls' means under each of the training treatments. None of these *t-values* were significant, but it will be noted that under all four training treatments the mean number of correct answers given by boys was higher than the mean number of correct answers given by girls. Because the assignment of students to daily CAI sessions was an administrative decision that depended to

Table 11

Kruskal-Wallis Rank Tests for Relative Proportions of Correct Words and Non-words under the Five Vowel-phonemes

			Words		
Vowel-phoneme	A	E	I	O	U
Sample size	13	15	15	12	17
Sum of ranks[a]	504	598	524	457	545
H-value (corrected for ties) = 1.459*					

			Non-words		
Vowel-phoneme	A	E	I	O	U
Sample size	13	15	15	12	17
Sum of ranks	510	554	541	496.5	526.5
H-value (corrected for ties) = 2.072*					

*Not significant; $\chi^2_{.95}(4) = 9.49$.

[a]Rank 1 was assigned to the subject with the smallest proportion of correct answers, rank 2 to the subject with the next smallest, etc.

Table 12

Means, Standard Deviations, and t-values for Numbers of Correct Responses by Boys and Girls under Each of the Four Training Treatments

		B	I	F	N
	Sample size	25	25	25	25
Boys	Mean correct	25.60	23.20	25.72	22.44
	Standard deviation	8.81	8.79	8.32	8.88
	Sample size	47	47	47	47
Girls	Mean correct	22.51	19.87	21.21	18.98
	Standard deviation	10.72	11.30	10.85	11.41
t-values for difference in means		1.235*	1.279*	1.811*	1.317*

*Not significant; $t_{.95}(70) = 2.00$.

some extent on the school, it might be argued that the criteria for selecting students for this investigation may have been biased in favor of more able boys than girls, but, in any case, there is no indication in these data that girls' performance was superior to boys' performance with respect to the tasks required.

DISCUSSION

Training Treatment

The data reflect the value of presenting spelling patterns in initial reading. Teaching spelling patterns to the subjects in this investigation resulted in positive transfer to a criterion task that required subjects to read words and non-words composed of the spelling patterns taught. Both the B training treatment and the F treatment resulted in performance on the criterion task that was significantly superior to performance under the N treatment.

These data corroborate earlier results reported by Fletcher and Atkinson (1972) who used a similar criterion task with eight words and eight non-words composed of spelling patterns taught in the Stanford CAI curriculum. Fletcher and Atkinson reported that in reading both the words and non-words, their 44 CAI subjects were superior to a matched sample of 44 non-CAI subjects.

The practical utility of the method is not well supported by the B treatment results. Under the B treatment, subjects correctly read about 66% of the items on the criterion task compared to 56% of the items under the N treatment. Given 240 presentations--(6 IC units + 6 FC units) * 20 presentations per unit--a gain greater than 10% might have resulted from presenting the 36 items directly.

The F treatment results provide better support for the practical utility of the method. Under the F treatment, subjects correctly read about 7% more of the criterion task items than they did under the N treatment. This gain is less--but not significantly less--than the gain resulting from the B treatment. However, the number of items made potentially available to subjects by the F treatment is much greater than the 36 items resulting from the combination of 6 IC units with 6 FC units under the B treatment. For instance, the six moderately productive FC units -IP, -IN, -IT, -ICK, -INT, and -IMP combine with initial consonants and consonant clusters to yield about 90 monosyllabic words. Further, the number of presentations required by the F treatment is one-half the number required by the B treatment.

The usefulness of the F treatment is probably not limited to reading monosyllabic words. Vocabulary gains among polysyllabic words are also likely. For instance, reading students may never encounter DIMP or BICK in isolation, but they may encounter DIMPLE or BICKER and, presumably, training with FC units will help them read these new words.

Beyond immediate gains in vocabulary, however, is the entire issue of 'learning to learn' as a form of transfer. If the orthographic rules for English are used in the reading process, then learning that such rules exist through practice with specific examples of these rules used in concrete applications may constitute an aspect of learning to learn in reading, and may be invaluable in initial reading instruction quite apart from specific increments in students' reading vocabularies.

Finally, the superiority of the F training treatment over the I treatment with respect to the criterion task is notable. Two explanations for this result are, first, that it reflects familiarity resulting from the use of FC units and non-use of IC units in 'linguistic' initial reading series, and, second, that it reflects the greater information--or reduction of uncertainty--provided by FC units on the pronunciation of the vowels in CVC's, CCVC's, CVCC's, and CCVCC's. The teachers of the three moderate-ability first grade classes from which all subjects were drawn used the Lippincott readers (1963) during most of the school year with most of their students. As mentioned earlier, these readers emphasize FC units, and familiarity is one plausible explanation for the superiority of the F training treatment among these subjects. The second hypothesis based on the information content of FC units seems equally plausible. Although a comprehensive comparison of the information carried by IC and FC units is beyond the scope of this study, informal evidence such as that of the MAT, MATE, MAR, MARE example lend credence to the hypothesis. Selection of one or the other of these hypotheses requires further experimentation.

Configuration

The criterion task items were expected to be ordered from easiest to most difficult as CVC, CCVC, CVCC, CCVCC. As expected, the CVC's were significantly easier than the CCVCC's. However, the CVCC's were about as easy as the CVC's and they were significantly easier than the CCVC's which were about as difficult as the CCVCC's. In other words, the data ordered the configurations on the basis of proportion correct as CVC = CVCC > CCVC = CCVCC. That the CVCC's were significantly easier than the CCVC's contradicts the result reported by Hansen and Rodgers (1968). However, Hansen and Rodgers used only six--two CCCVC, two CCVCC, and two

CVCCC--monosyllabic non-words for all their subjects and their results may have been peculiar to the particular set of items they used.

Some interaction between configuration and training was expected. Specifically, the I treatment should have facilitated reading CCVC's on the criterion task at the expense of CVCC's, despite generally higher proportions of correct CVCC's than CCVC's over all treatments. This effect was observed for non-word items under the I treatment but not for word items. The former result implies the expected interaction; the latter result may be due to subjects' prior familiarity with the word items.

Words and Non-words

The proportion of correct responses was expected to be greater for words than for non-words, and this expectation was supported by the data. Words were significantly easier than non-words under each of the four treatments.

An interaction of this effect with training treatment was also expected. Under the N treatment subjects could draw only on their prior experience in reading the criterion task items, and, presumably this experience was entirely with words. Under the B treatment, the effect of prior experience could be drastically reduced since the training was designed only to relate spelling to sound and did not discriminate between words and non-words. This expectation was not supported by the data; no significant effect due to the four training treatments was observed on the proportions of correctly read words relative to non-words. For that matter, the results seemed to be in exactly the opposite direction from that expected. Among the four training treatments, the frequency with which the proportion of correct words exceeded the proportion of correct non-words was highest under the B treatment and lowest under the N treatment.

Vowel-phoneme

No effect due to the vowel-phoneme association required by the spelling patterns and the criterion task items was expected, and none was found. Such an effect was not considered out of the question, rather, the design of this investigation was considered to be insensitive to this effect, and the data were not expected to reflect it. It should be noted that for both words and non-words criterion task items with E = /e/ were easiest and items with O = /a/ were the most difficult. A separate investigation that directly compared E = /e/ with O = /a/ might indicate that the former association is genuinely easier than the latter for students in the school district. Dialect differences in phonology between the Black English used by nearly all the subjects in this study and the audio messages recorded for the Stanford CAI curriculum might well be reflected by the relative ease or difficulty with which the student population learns given grapheme-phoneme correspondences.

Sex

Despite the long noted superiority of girls' initial reading performance over boys', no such effect was evident in this investigation. This result corroborates similar findings for CAI in initial reading reported by Atkinson (1968) and Fletcher and Atkinson (1972). It is difficult to say if the absence of superior performance by girls resulted from CAI itself, from the nature of the CAI reading curriculum, or from the removal of the students from classrooms for their CAI sessions.

Jeffrey and Samuels (1967) reported a similar result in their study of phonics based initial reading instruction and so did McNeil (1964) in his study of programmed instruction in initial reading given to kindergarten students. McNeil's study is particularly interesting because superior reading performance by the girls in his sample population was noted after his subjects were advanced to ordinary classroom instruction in first grade.

All these studies, including the present investigation, indicate that the superiority of girls in initial reading is not due to an inherent, maturational factor but in some way results from ordinary classroom instruction. The Stanford CAI curriculum avoids whatever biases classroom instruction in favor of girls' initial reading performance as successfully as did the phonics instruction given by Jeffrey and Samuels and the programmed instruction given by McNeil.

Reading as Rule-governed Behavior

In 1908, Huey emphasized that

> perceiving is an act, a thing that we do, always and everywhere, never a mere passive sensing of a group of passing sensations or impressions. It probably always involves actual innervation of muscles, and indeed coordinated and organized, we may say unitized, innervation of muscles. Certainly on the psychic side there is an active and more or less unitized movement of mind, a sense of inner activity [p. 104].

There can be little doubt that, at the syntactic level, reading is active, rule-governed behavior. Every day we encounter novel combinations of textual information that we read and understand without a second glance. It seems reasonable to assume that reading is active, rule-governed behavior at the orthographic level as well. Efforts by Chomsky and Halle, Venezky, and Cronnell all suggest an elaborate and comprehensive system of orthography that can be expressed as a series of generative rules for mapping spelling patterns onto more abstract representations of language. Whatever these abstract representations may be, the rules mapping spelling patterns into them will necessarily be more complex than the simple grapheme-phoneme correspondences used in this investigation. For example, morphology may explain why TH in HOTHOUSE is pronounced as /th/ rather than as /ð/ in BATHE or as /θ/ in BATHROOM, and stress may explain the palatalization of /t/ in VENTURE and not in VENTURA.

Obviously, a major contribution to reading research would be to develop empirically based notions of how rules of English orthography are applied in the reading process. This contribution requires more sophisticated experimentation than that attempted in this investigation. However, systematic studies of English spelling patterns in the sense of grapheme-phoneme correspondences should continue to be useful in laying groundwork. Contradictions may appear that require a notion such as lexical representation for their resolution, but, for the time being, our information on reading performance with grapheme-phoneme correspondences can stand considerable expansion before we begin investigating reading competence by examining the 'psychological reality' of rules that relate orthography to progressively more abstract representations of language.

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APPENDIX A

Initial Units, Final Units, and Criterion Task Target Items

a ← /æ/

ca■	cla■	■ad	■and
la■	gra■	■ag	■ast
ra■	sla■	■am	■ack
pa■	cra■	■an	■ath
ma■	fla■	■ab	■amp
ha■	sta■	■at	■ash

cad■w	cag■n	cam■w	can■w	cab■w	cat■w
lad■w	lag■w	lam■n	lan■n	lab■w	lat■w
rad■n	rag■w	ram■w	ran■w	rab■n	rat■w
pad■w	pag■n	pam■w	pan■w	pab■n	pat■w
mad■w	mag■n	mam■n	man■w	mab■w	mat■w
had■w	hag■w	ham■w	han■n	hab■n	hat■w
clad■w	clag■n	clam■w	clan■w	clab■n	clat■n
grad■w	grag■n	gram■w	gran■n	grab■w	grat■n
slad■n	slag■w	slam■w	slan■n	slab■w	slat■w
crad■n	crag■w	cram■w	cran■n	crab■w	crat■n
flad■n	flag■w	flam■w	flan■w	flab■n	flat■w
stad■n	stag■w	stam■n	stan■w	stab■w	stat■n

cand■n	cast■w	cack■n	cath■n	camp■w	cash■w
land■w	last■w	lack■w	lath■w	lamp■w	lash■w
rand■w	rast■n	rack■w	rath■n	ramp■w	rash■w
pand■n	past■w	pack■w	path■w	pamp■n	pash■n
mand■n	mast■w	mack■w	math■w	mamp■n	mash■w
hand■w	hast■n	hack■w	hath■n	hamp■n	hash■w
cland■n	clast■n	clack■w	clath■n	clamp■w	clash■w
grand■w	grast■n	grack■n	grath■n	gramp■n	grash■n
sland■n	slast■n	slack■w	slath■n	slamp■n	slash■w
crand■n	crast■n	crack■w	crath■n	cramp■w	crash■w
fland■n	flast■n	flack■n	flath■n	flamp■n	flash■w
stand■w	stast■n	stack■w	stath■n	stamp■w	stash■n

e ← /e/

be■	che■	■et	■end
ne■	fre■	■eb	■eck
se■	pre■	■em	■elt
fe■	swe■	■en	■ent
te■	dre■	■ep	■est
le■	spe■	■ed	■eld

bet■w	beb■n	bem■n	ben■w	bep■n	bed■w
net■w	neb■w	nem■n	nen■n	nep■n	ned■w
set■w	seb■n	sem■n	sen■w	sep■n	sed■n
fet■n	feb■n	fem■n	fen■w	fep■n	fed■w
tet■n	teb■n	tem■n	ten■w	tep■n	ted■w
let■w	leb■n	lem■n	len■n	lep■n	led■w
chet■n	cheb■n	chem■n	chen■n	chep■n	ched■n
fret■w	freb■n	frem■n	fren■n	frep■n	fred■w
pret■n	preb■n	prem■n	pren■n	prep■w	pred■n
swet■n	sweb■n	swem■n	swen■n	swep■n	swed■n
dret■n	dreb■n	drem■n	dren■n	drep■n	dred■n
spet■n	speb■n	spem■n	spen■n	spep■n	sped■w

bend■w	beck■w	belt■w	bent■w	best■w	beld■n
nend■n	neck■w	nelt■n	nent■n	nest■w	neld■n
send■w	seck■n	selt■n	sent■w	sest■n	seld■n
fend■w	feck■n	felt■w	fent■n	fest■n	feld■n
tend■w	teck■n	telt■n	tent■w	test■w	teld■n
lend■w	leck■n	lelt■n	lent■w	lest■n	leld■n

chend■n	check■w	chelt■n	chent■n	chest■w	cheld■n
frend■n	freck■n	frelt■n	frent■n	frest■n	freld■n
prend■n	preck■n	prelt■n	prent■n	prest■w	preld■n
swend■n	sweck■n	swelt■n	swent■n	swest■n	sweld■n
drend■n	dreck■n	drelt■n	drent■n	drest■w	dreld■n
spend■w	speck■w	spelt■w	spent■w	spest■n	speld■n

ɨ ◆ /ɪ/

fɨ■	chɨ■	■ɨd	■ɨlt
hɨ■	twɨ■	■ɨp	■ɨck
lɨ■	spɨ■	■ɨm	■ɨsk
mɨ■	drɨ■	■ɨn	■ɨst
sɨ■	trɨ■	■ɨt	■ɨnt
dɨ■	skɨ■	■ɨg	■ɨmp

fɨd■w	fɨp■n	fɨm■n	fɨn■w	fɨt■w	fɨg■w
hɨd■w	hɨp■w	hɨm■w	hɨn■n	hɨt■w	hɨg■n
lɨd■w	lɨp■w	lɨm■n	lɨn■n	lɨt■w	lɨg■n
mɨd■w	mɨp■n	mɨm■w	mɨn■n	mɨt■n	mɨg■n
sɨd■w	sɨp■w	sɨm■n	sɨn■w	sɨt■w	sɨg■n
dɨd■w	dɨp■w	dɨm■w	dɨn■w	dɨt■n	dɨg■w
chɨd■n	chɨp■w	chɨm■n	chɨn■w	chɨt■w	chɨg■n
twɨd■n	twɨp■n	twɨm■n	twɨn■w	twɨt■w	twɨg■w
spɨd■n	spɨp■n	spɨm■n	spɨn■w	spɨt■w	spɨg■n
drɨd■n	drɨp■w	drɨm■n	drɨn■n	drɨt■n	drɨg■n
trɨd■n	trɨp■w	trɨm■w	trɨn■n	trɨt■n	trɨg■w
skɨd■w	skɨp■w	skɨm■w	skɨn■w	skɨt■w	skɨg■n
fɨlt■n	fɨck■n	fɨsk■w	fɨst■w	fɨnt■n	fɨmp■n
hɨlt■w	hɨck■w	hɨsk■n	hɨst■n	hɨnt■w	hɨmp■n
lɨlt■w	lɨck■w	lɨsk■n	lɨst■w	lɨnt■w	lɨmp■w
mɨlt■w	mɨck■n	mɨsk■n	mɨst■w	mɨnt■w	mɨmp■n
sɨlt■w	sɨck■w	sɨsk■n	sɨst■n	sɨnt■n	sɨmp■w
dɨlt■n	dɨck■w	dɨsk■w	dɨst■n	dɨnt■w	dɨmp■n
chɨlt■n	chɨck■w	chɨsk■n	chɨst■n	chɨnt■n	chɨmp■n
twɨlt■n	twɨck■n	twɨsk■n	twɨst■w	twɨnt■n	twɨmp■n
spɨlt■w	spɨck■n	spɨsk■n	spɨst■n	spɨnt■n	spɨmp■n
drɨlt■n	drɨck■n	drɨsk■n	drɨst■n	drɨnt■n	drɨmp■n
trɨlt■n	trɨck■w	trɨsk■n	trɨst■n	trɨnt■n	trɨmp■n
skɨlt■n	skɨck■n	skɨsk■n	skɨst■n	skɨnt■n	skɨmp■w

o ← /a/

lo■	cro■	■od	■ock
ho■	flo■	■ot	■ond
co■	sho■	■om	■oft
ro■	clo■	■on	■ong
po■	pro■	■ob	■osh
mo■	sto■	■og	■oth

lod■n	lot■w	lom■n	lon■n	lob■w	log■w
hod■w	hot■w	hom■n	hon■n	hob■w	hog■w
cod■w	cot■w	com■n	con■w	cob■w	cog■w
rod■w	rot■w	rom■w	ron■w	rob■w	rog■n
pod■w	pot■w	pom■n	pon■n	pob■n	pog■n
mod■n	mot■w	mom■w	mon■n	mob■w	mog■n
crod■n	crot■n	crom■n	cron■n	crob■n	crog■n
flod■n	flot■n	flom■n	flon■n	flob■n	flog■w
shod■w	shot■w	shom■n	shon■n	shob■n	shog■n
clod■w	clot■w	clom■n	clon■n	clob■n	clog■w
prod■w	prot■n	prom■w	pron■n	prob■n	prog■n
stod■n	stot■n	stom■n	ston■n	stob■n	stog■n
lock■w	lond■n	loft■w	long■w	losh■n	loth■w
hock■w	hond■n	hoft■n	hong■w	hosh■n	hoth■n
cock■w	cond■n	coft■n	cong■n	cosh■n	coth■n
rock■w	rond■n	roft■n	rong■n	rosh■n	roth■n
pock■w	pond■w	poft■n	pong■n	posh■n	poth■n
mock■w	mond■n	moft■n	mong■n	mosh■n	moth■w
crock■w	crond■n	croft■w	crong■n	crosh■n	croth■n
flock■w	flond■n	floft■n	flong■n	flosh■n	floth■n
shock■w	shond■n	shoft■n	shong■n	shosh■n	shoth■n
clock■w	clond■n	cloft■n	clong■n	closh■n	cloth■w
prock■n	prond■n	proft■n	prong■w	prosh■n	proth■n
stock■w	stond■n	stoft■n	stong■n	stosh■n	stoth■n

u ← /ə/

bu▪	cru▪		▪ud	▪ung	
su▪	dru▪		▪up	▪uck	
hu▪	sku▪		▪um	▪ump	
lu▪	gru▪		▪ug	▪unt	
mu▪	tru▪		▪un	▪ust	
ru▪	plu▪		▪ut	▪unk	

bud▪w	bup▪n	bum▪w	bug▪w	bun▪w	but▪w
sud▪n	sup▪w	sum▪w	sug▪n	sun▪w	sut▪n
hud▪n	hup▪n	hum▪w	hug▪w	hun▪w	hut▪w
lud▪n	lup▪n	lum▪n	lug▪w	lun▪n	lut▪n
mud▪w	mup▪n	mum▪w	mug▪w	mun▪n	mut▪n
rud▪n	rup▪n	rum▪w	rug▪w	run▪w	rut▪w

crud▪n	crup▪n	crum▪n	crug▪n	crun▪n	crut▪n
drud▪n	drup▪n	drum▪w	drug▪w	drun▪n	drut▪n
skud▪n	skup▪n	skum▪n	skug▪n	skun▪n	skut▪n
grud▪n	grup▪n	grum▪n	grug▪n	grun▪n	grut▪n
trud▪n	trup▪n	trum▪n	trug▪n	trun▪n	trut▪n
plud▪n	plup▪n	plum▪w	plug▪w	plun▪n	plut▪n

bung▪w	buck▪w	bump▪w	bunt▪w	bust▪w	bunk▪w
sung▪w	suck▪w	sump▪w	sunt▪n	sust▪n	sunk▪w
hung▪w	huck▪w	hump▪w	hunt▪w	hust▪n	hunk▪w
lung▪w	luck▪w	lump▪w	lunt▪n	lust▪w	lunk▪n
mung▪n	muck▪w	mump▪n	munt▪n	must▪w	munk▪n
rung▪w	ruck▪w	rump▪w	runt▪w	rust▪w	runk▪n

crung▪n	cruck▪n	crump▪w	crunt▪n	crust▪w	crunk▪n
drung▪n	druck▪n	drump▪n	drunt▪n	drust▪n	drunk▪w
skung▪n	skuck▪n	skump▪n	skunt▪n	skust▪n	skunk▪w
grung▪n	gruck▪n	grump▪n	grunt▪w	grust▪n	grunk▪n
trung▪n	truck▪w	trump▪w	trunt▪n	trust▪w	trunk▪w
plung▪n	pluck▪w	plump▪w	plunt▪n	plust▪n	plunk▪w

APPENDIX B

Initial Units, Final Units, and Exemplars

ca■	camera	cap
la■	landed	lap
ra■	rabbit	raft
pa■	pattern	pass
ma■	magic	mask
ha■	hammer	has
cla■	clatter	clap
gra■	grandma	grant
sla■	slander	slant
cra■	crackers	craft
fla■	flatter	flax
sta■	statue	staff
■ad	nomad	glad
■ag	dishrag	tag
■am	program	jam
■an	began	plan
■ab	prefab	nab
■at	acrobat	fat
■and	unhand	sand
■ast	contrast	blast
■ack	attack	crack
■ath	footpath	bath
■amp	encamp	damp
■ash	potash	trash

be■	bedbug	bell
ne■	never	next
se■	seven	self
fe■	fellow	fell
te■	telephone	tell
le■	lesson	left
che■	cherry	chess
fre■	fretful	fresh
pre■	present	press
swe■	sweater	swept
dre■	dressing	dress
spe■	special	spell
■et	regret	jet
■eb	cobweb	web
■em	anthem	stem
■en	golden	den
■ep	instep	step
■ed	abed	red
■end	defend	mend
■eck	henpeck	wreck
■elt	heartfelt	melt
■ent	prevent	rent
■est	protest	vest
■eld	beheld	held

fi-	fifty	fish
hi-	hidden	hill
li-	listen	lift
mi-	minute	mix
si-	sister	silk
di-	dinner	dish
chi-	chicken	chill
twi-	twisted	twill
spi-	spinach	spill
dri-	driven	drift
tri-	tricked	trill
ski-	skipped	skill
-id	timid	slid
-ip	turnip	snip
-im	pilgrim	tim
-in	cabin	grin
-it	admit	flit
-ig	whirligig	big
-ilt	vanderbilt	tilt
-ick	lipstick	kick
-isk	asterisk	frisk
-ist	dentist	wrist
-int	peppermint	print
-imp	shrimp	blimp

lo■	lollipop	lost
ho■	hopped	hop
co■	cotton	cost
ro■	robin	ross
po■	pocket	pop
mo■	monster	moss
cro■	crossing	cross
flo■	flocking	flop
sho■	shopping	shop
clo■	closet	clop
pro■	promise	prop
sto■	stocking	stop
■od	ramrod	nod
■ot	apricot	not
■om	pompom	tom
■on	upon	don
■ob	doorknob	job
■og	leapfrog	dog
■ock	peacock	block
■ond	beyond	blond
■oft	aloft	soft
■ong	prolong	wrong
■osh	galosh	gosh
■oth	dishcloth	broth

bu-	bucket	buzz
su-	sudden	such
hu-	hundred	hub
lu-	lumber	luff
mu-	mustache	much
ru-	rushed	rub
cru-	crusted	crumb
dru-	drugstore	drub
sku-	skulking	skull
gru-	grumble	gruff
tru-	trumpet	truss
plu-	plunder	plus
-ud	rosebud	thud
-up	ketchup	cup
-um	maximum	gum
-ug	bedbug	tug
-un	begun	spun
-ut	chestnut	cut
-ung	unsung	stung
-uck	firetruck	stuck
-ump	overtrump	lump
-unt	fox-hunt	stunt
-ust	august	just
-unk	chipmunk	junk