DOCUMENT RESUME

ED 066 736 24 CS 200 071

AUTHOR Calfee, Robert C.; And Others
TITLE Pronunciation of Synthetic Words with Predictable and Unpredictable Letter-Sound Correspondences. Technical Report No. 71.
INSTITUTION Wisconsin Univ., Madison. Research and Development Center for Cognitive Learning.
SPONS AGENCY Office of Education (DHEW), Washington, D.C. Cooperative Research Program.
REPORT NO TR-71
BUREAU NO BR-5-0216
PUB DATE Feb 69
CONTRACT OEC-5-10-154
NOTE 22p.

EDRS PRICE MF-$0.65 HC-$3.29
DESCRIPTORS *Artificial Speech; College Students; Comparative Analysis; Grade 3; Grade 6; Grade 11; Linguistic Performance; Phonetics; *Pronunciation; *Reading Processes; *Reading Research; *Reading Skills; Research Methodology; Research Reviews (Publications); Word Lists; Word Recognition

ABSTRACT

The acquisition of Literacy Project's basic goal is to determine the processes by which children learn to read, and to identify reasons many fail to learn. One part of the process is the formation of correspondences between letter patterns and the sounds for which they stand. To determine the extent of such correspondences, tests of pronunciation of synthetic words were conducted. A list of these words was prepared to test the pronunciation of predictable patterns, such as (final "e", "c" before "e" and "i", and "c" before "a", "o" and "u"), and unpredictable patterns (vowel digraph spellings such as "ai" and "ou"). Responses were recorded and transcribed by graduate students trained in phonetics. Participants were third, sixth and eleventh graders, and college students. A good third grade reader showed mastery of predictable letter-sound correspondences. This mastery increased through high school, but correlation with reading achievement decreased, presumably because this ability is only one of many necessary for skilled reading. Poor readers made more and wild errors in correspondences than good readers. (Author/GR)

PRONUNCIATION OF SYNTHETIC WORDS WITH PREDICTABLE AND UNPREDICTABLE LETTER-SOUND CORRESPONDENCES

WISCONSIN RESEARCH AND DEVELOPMENT

CENTER FOR
COGNITIVE LEARNING

Technical Report No. 71

PRONUNCIATION OF SYNTHETIC WORDS WITH PREDICTABLE AND UNPREDICTABLE LETTER-SOUND CORRESPONDENCES

By Robert C. Calfee, Richard L. Venezky, and Robin S. Chapman

Report from the Project on Language Concepts and Cognitive Skills
Related to the Acquisition of Literacy
Robert C. Calfee and Richard L. Venezky, Principal Investigators

Wisconsin Research and Development Center
for Cognitive Learning
The University of Wisconsin
Madison, Wisconsin

February 1969

The research reported herein was performed pursuant to a contract with the United States Office of Education, Department of Health, Education, and Welfare, under the provisions of the Cooperative Research Program. The opinions expressed in this publication do not necessarily reflect the position or policy of the Office of Education and no official endorsement by the Office of Education should be inferred.

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The Wisconsin Research and Development Center for Cognitive Learning focuses on contributing to a better understanding of cognitive learning by children and youth and to the improvement of related educational practices. The strategy for research and development is comprehensive. It includes basic research to generate new knowledge about the conditions and processes of learning and about the processes of instruction, and the subsequent development of research-based instructional materials, many of which are designed for use by teachers and others for use by students. These materials are tested and refined in school settings. Throughout these operations behavioral scientists, curriculum experts, academic scholars, and school people interact, insuring that the results of Center activities are based soundly on knowledge of subject matter and cognitive learning and that they are applied to the improvement of educational practice.

This Technical Report is from the Language Concepts and Cognitive Skills Related to the Acquisition of Literacy Project in Program 1. General objectives of the Program are to generate new knowledge about concept learning and cognitive skills, to synthesize existing knowledge, and to develop educational materials suggested by the prior activities. Contributing to these Program objectives, this project's basic goal is to determine the processes by which children aged four to seven learn to read and to identify the specific reasons why many children fail to acquire this ability. Later studies will be conducted to find experimental techniques and tests for optimizing the acquisition of skills needed for learning to read.

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ABSTRACT

A child learns to read by first learning to translate from visual symbols to sound. One part of this process is the formation of correspondences between letter patterns and the sounds for which they stand. Recent linguistic research has revealed more regularity in letter-sound correspondences than was previously thought. A major concern of the study reported here was to find the extent to which readers used such correspondences in pronouncing synthetic words, and how they pronounced synthetic words for which no such regular correspondences existed.

A list of synthetic words was prepared for testing the pronunciation of predictable patterns (final *-e*, *c* before *e* and *i*, and *c* before *a*, *o*, and *u*), unpredictable patterns (vowel digraph spellings such as *ai*, *ou*), and miscellaneous spellings (*th*, final *-s*). For the predictable patterns, the appropriate responses were taken to be the long form of the vowel for final *-e* patterns (*rate*, *mete*, *bite*, *rote*, *cute*), *c* pronounced /s/ before *e* and *i* (*cell*, *city*), and *c* pronounced /k/ before *a*, *o*, and *u* (*cake*, *coke*, *cute*). A 40-item list and 5 pretraining items, prepared on slides in capital letters, were presented to *S*s in one of two random orders. Responses were recorded and transcribed by graduate students trained in phonetics. Participating in the study were third and sixth graders from two elementary schools, eleventh graders, and college students.

It was found that, to the extent that a child in third grade was identified as a good reader, he showed some mastery of predictable letter-sound correspondences. This mastery increased through high school, but the correlation with reading achievement decreased, presumably because this ability is only one of many necessary for skilled reading. Poor readers made more and "wilder" errors on predictable patterns and gave less consistent responses to unpredictable spellings.

I
LETTER-SOUND CORRESPONDENCES

Analysis of grapheme-phoneme relationships based on the 20,000 most frequent English words has revealed a greater degree of patterning than was assumed previously (Venezky, 1967). While English orthography is far from a one-letter, one-sound system, graphemic, morphemic, and phonemic clues exist or predicting many pronunciations.[1] Many letters, like *d*, *f*, *j*, *l*, *q*, *v*, and *z*, have invariant or nearly invariant pronunciations. Others, like *b*, *c*, and *m*, have variant correspondences which can be predicted on the basis of their graphemic environment. For example, initial *c* corresponds to /s/ before the spellings *e*, *i*, or *y*; (*cell*, *city*, *cyst*); otherwise, it corresponds to /k/ (*cake*, *coke*, *cute*).[2]

Some correspondences, while predictable, occur too infrequently to be classed as rules. Initial *gh*, for example, is always pronounced /g/, yet it occurs only in *ghost*, *ghoul*, *gherkin*, *ghastly*, and *ghetto*. It is unlikely that most readers would acquire a correspondence from so few examples. Often the form class of a word determines the pronunciation of some of its letters. For example, final *-ate* is generally /-ɪt/ in nouns and adjectives, but /-et/ in verbs; cf. *delegate* (n): *delegate* (v): *duplicate* (adj.): *duplicate* (v):

Each single-letter vowel spelling—*a*, *e*, *i*, *y*, *o*, *u*—has two major pronunciations, usually referred to as the long and short pronunciations. The long pronunciation generally occurs when the vowel letter is followed by a simple consonant unit and then another vowel spelling (including final, silent *-e*).[3] Otherwise, the short pronunciation occurs. Compare, for example, *rate*:*rat*, *mete*:*met*, *site*:*sit*, *pope*:*pop*, *cube*:*cub*, and *anal*:*annals* (the first *a* spelling), and *super*:*supper*. The final *-e* in forms like *rate* and *mete* is a *marker*; that is, it has no pronunciation of its own, but indicates the pronunciation of some other letter or letters. In *rage*, *-e* marks both the long pronunciation of *a* and the /ʒ/ pronunciation of *g* (cf. *rag*). Sometimes *markers* mark morphemic rather than phonemic patterns. For example, in *house* and *moose*, *-e* indicates that the *s* is not a marker of plurality.

Digraph vowel spellings generally have a single, high frequency pronunciation, but may have several other low frequency pronunciations. These pronunciations are seldom predictable, except in isolated circumstances. For example, *oo* is generally pronounced /u/, as in *loop* and *noon*. Before final *k*, however, *oo* is /ʊ/, as in *book*, *look* and *shook* (*spook* is an exception).

It has been shown that good readers, even if taught to read by whole word methods, make some letter-sound generalizations (Bishop, 1964). These generalizations should aid the reader in pronouncing words he has not seen before. Even though the set of possible letter-sound generalizations is far from exhaustive for the letter-sound correspondences (LSCs) which occur in English, such generalizations still aid a reader in approximating the pronunciation of unfamiliar words. Furthermore, if the reader knows the allowable range of pronunciations for a letter or letter sequence, he may by trial and error connect an unfamiliar visual sequence with a known pronunciation.

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[1]IPA symbols will be used to indicate pronunciation.

[2]*Cello* and a few other rare Italian borrowings are exceptions. For medial *c*, vowel patterns plus stress determine whether *c* is /š/, /s/, or /k/, as in *social*, *recede*, or *acute*.

[3]A simple consonant unit is any single consonant except *x*, and any of the digraphs *ch*, *gh*, *ph*, *rh*, *sh*, and *th*. A few exceptions to the vowel rule do exist (e.g. *love*, *lose*, *have*), but they are infrequent.

In the study reported here, the ability of children and adults to employ letter-sound generalizations was explored. The questions we attempted to answer are:

a. How well can readers use certain LSCs in pronouncing unfamiliar words?
b. When the pronunciation of a letter (or letters) is not predictable, how do readers respond to it?
c. How do letter-sound generalizations develop?
d. Is there a pattern to the errors made in pronouncing letters which have predictable correspondences?
e. What differences are there in the pronunciation strategies of good and poor readers?

II
METHOD

STIMULUS MATERIALS

A list of 40 synthetic words and a pretraining list of 5 synthetic words were prepared.[4] In the absence of any information about what comparisons might be most interesting, the synthetic words were selected to cover a variety of spelling patterns, including the predictable final *-e* and initial *c* patterns and the unpredictable vowel digraph patterns. The experimental items are listed in Table 1 according to spelling patterns. Three of the items—*mien*, *lethe*, and *leek*—were actually low-frequency English words. A 35mm slide was made of each item typed in *sans-serif* capital letters. Two random orders of the 5 pretraining items and the 40-item list were prepared.

[4]The list presented to college students differed in certain respects from the one described, which was used for all other groups. The CSW list contained 135 items, 38 of which were identical or similar to the experimental items in Table 1. Non-identical items were *cide* for *cipe*, *cuse* for *cune*, and *cepc* for *cerp*. Missing items in the CSW list were *houm* and *veeg*.

PROCEDURE

Each *S* was brought to an experimental room, given a microphone, and instructed in how to hold it while a proper recording level was established on the Uher 7000S stereo recorder. He was then told that he would see a series of synthetic words and that he was to pronounce each of these words as if it were a regular English word. Half of each class was assigned at random to each order of the list. High school and college students were especially warned not to treat the items as foreign words. Presentation rate of the slides by a Kodak Carousel remote-controlled projector was *S*-paced. Younger children were encouraged not to take too long.

Table 1. Experimental Words Classed According to Spelling Patterns

Final *-e*	Initial and Medial *c*	Vowel Digraph			Miscellaneous	
					s	*ch*
cabe	cabe*	baig	theat	yook	thaus*	chait*
clase	cofe*	kaip	peaz	shoog	cose*	chung
gare	cose*	chait	veeg	voop	clase*	chal
lethe	cune*	thaid	neem	poup	*th*	moch
cipe	cerp	dauk	leek	houm		
cofe	cipe*	laum	sheip		thaus*	*gh*
cose	acol	kaut	vieb		theat*	
cune	acil	thaus	yiet		thaid*	ghin
			mien			ghim
						ghal
						final -c
						roc

*Indicates words entering into more than one spelling pattern comparison.

Latency of response to each item was measured later from the click of the slide projector (on one tape channel) to the beginning of a complete response (on the other tape channel) by means of an automated card punch device accurate to within .10 second.

A phonetic transcription of each student's data was made by a trained linguist from the tape recording, and an independent check of a random sample of the data was made by a second linguist. No major disagreements were found in the check.

Background information was collected for each student on reading ability (tests of reading skill or teacher ratings), IQ, grade point average, exposure to foreign languages, and whether or not the student had lived outside the upper Midwest region of the country. High school and college students were asked after the test session to state those factors which they felt influenced their pronunciations on the test.

SUBJECTS

Elementary school students were drawn from third and sixth grades of Huegel (H), a middle class school in Madison, Wisconsin, and Wilson (W), a lower-middle class school in Janesville, Wisconsin. Eleventh and twelfth grade *S*s came from Oconomowoc (HSO), a high school in Oconomowoc, near Milwaukee College-age subjects (CSW) were drawn from a beginning psychology class at the University of Wisconsin in Madison. A total of 247 students took part in the study. The students in each group were divided into High (or good) and Low (or poor) reading subgroups by a median split on the basis of available reading test scores, teacher ratings (HSO), or grade point average (CSW). Background data for each group of students in the study are presented in Table 2.

Table 2. Background Data on Students

Code	3H	6H	3W	6W	HSO	CSW
Grade	3	6	3	6	11, 12	College
School[a]	Huegel	Huegel	Wilson	Wilson	Oconomowoc	University of Wisconsin, Madison
	(middle, upper-middle class students in Madison)		(lower-middle class students in Janesville, Wisconsin)		(middle, upper-middle class students, near Milwaukee)	
No. of subjects	37	27	60	69	32	22
High Readers						
Males	8	6	17	15	8	4
Females	10	8	12	19	8	5
Reading Percentile[b]	84	85	73	49	B+	above 2.75
IQ[c]	118	118	103	112	--	--
Low Readers						
Males	12	9	18	18	8	6
Females	7	4	13	17	8	7
Reading Percentile[b]	36	57	28	14	C-	below 2.75
IQ[c]	104	107	96	94	--	--

[a] On both reading and intelligence tests, students at Huegel School scored higher than those at Wilson. For reading (but not intelligence) scores, the gap was substantially greater at the sixth than the third grade. The design of the present study does not permit any strong test of the reliability of this finding. However, Coleman (1966) reports a similar trend toward relatively poorer performance by lower socioeconomic pupils as grade level increases. Note also that the poor readers at Huegel improve from the third to sixth grade, but the poor readers at Wilson are getting worse.

[b] The reading tests available were: 3H, Gates-MacGinitie; 6H, Iowa Tests of Basic Skills; 3W, Stanford Achievement Test (Word Study Subtest); 6W, Stanford Achievement Test (Language Subtest); HSO, grade; CSW, grade point average, 2.0 equals C, 3.0 equals B.

[c] IQ was measured by: 3H, California Mental Maturity Test; 6H, California Mental Maturity Test; 3W, Lorge-Thorndike; 6W, Lorge-Thorndike. For high school and college students, no IQ measure was available.

III
RESULTS

PRONUNCIATION OF PREDICTABLE PATTERNS

Appropriate Responses

Figures 1, 2, and 3 show the percentage of correct responses to spelling patterns which have predictable pronunciations: the vowel letter in final -*e* patterns (long form); *c* before *e* or *i* (/s/); and *c* before *a*, *o*, or *u* (/k/).

Three generalizations can be drawn from these pronunciations of predictable patterns. First, the percentage of appropriate pronunciations increases from third grade through high school. Only for *c* before *e* or *i* patterns do college students surpass high school students. Second, better readers in third and sixth grades are consistently more likely than poorer readers to give appropriate responses to predictable patterns. Good and poor readers continue to differ in the final -*e* pattern even through college. Third, certain predictable patterns are not totally mastered even by the better or older readers. For final -*e* and *c* before *e* and *i* patterns, at least

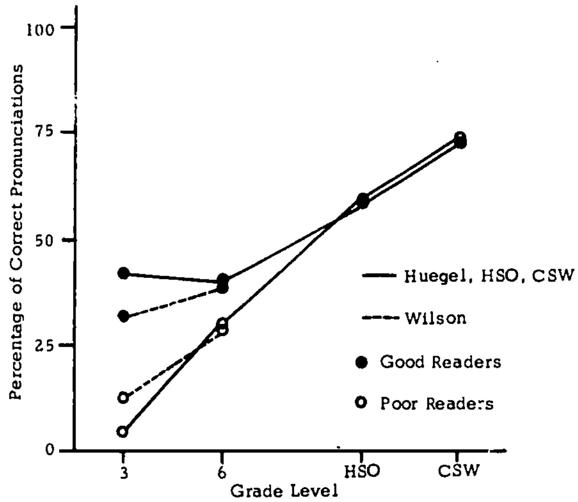

Fig. 2. Percentage of correct pronunciations of *c* followed by *e* or *i*.

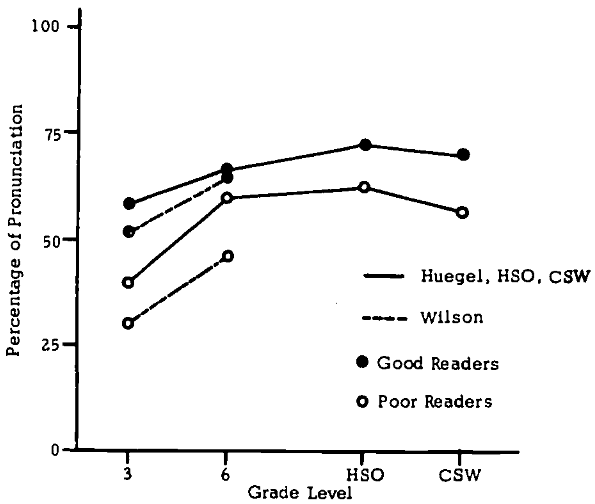

Fig. 1. Percentage of correct pronunciations of vowels in final -*e* patterns

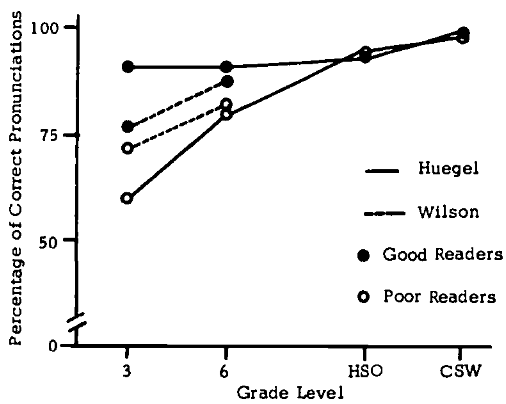

Fig. 3. Percentage of correct pronunciations of *c* followed by *a*, *o*, or *u*.

25% of the responses were inappropriate for the best subgroups. The high percentage of /k/ pronunciations of *c* before *a*, *o*, or *u* at all grades suggests a response bias to pronounce *c* as /k/.

Differences among groups were estimated by a more detailed analysis of errors on final *-e* patterns and *c* before *e* or *i* patterns. College *S*s were excluded from this analysis since they received a slightly different version of the test. Eleven test items were included in the analysis: the eight final *-e* test items and the three items testing *c* before *e* or *i*. (Items testing *c* before *a*, *o*, or *u* were excluded since correct responses were likely to arise simply through response bias.) Each *S* was assigned a score of 0 to 11, depending on the number of appropriate responses.

Analysis of variance of the scores in a 5 x 2 design (grade and school x reading group) revealed a reliable difference associated with the five classes (3H, 3W, 6H, 6W, HSO), $F(4,213) = 14.6$, $p < .01$. Good and poor readers differed significantly in the scores achieved, $F(1,213) = 45.7$, $p < .01$.

Duncan range tests revealed no significant differences between Huegel and Wilson scores (the two elementary schools which differed in socioeconomic level). The poorer third grade readers in both schools were significantly worse than other groups at giving appropriate pronunciations ($p < .01$).

Spearman rank-order correlations between *S*s' scores on the eleven test items and their reading scores are reported in Table 3.[5] Reliable positive correlations were observed ($p < .05$) for all classes except 6H. Spearman rank-order correlations between IQ scores and pronunciation scores and between IQ and reading scores were also calculated; they are recorded in Table 3. Reliable positive correlations were observed ($p < .05$) for all cases except the pronunciation–IQ correlation for 3W. In third grade, *S* pronunciation scores are more highly correlated than IQ scores with reading; in sixth grade, however, IQ is a better predictor of reading rank than is the pronunciation score.

The mean pronunciation score for elementary school girls was 5.48; for boys, 4.67. The tendency for girls to receive slightly higher scores than boys was confirmed by the significance of the overall comparison ($p < .025$). Comparisons by *t* tests of mean pronunciation scores of male and female *S*s in each elementary school class, however, revealed no significant differences.

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[5]Analysis of covariance, which would have combined anova and the correlational analysis, was considered inappropriate for several reasons, the most important being that different reading tests were administered to each group.

Table 3. Spearman Rank-Order Correlations of Pronunciation, Reading, and IQ Scores[a]

School & Grade	N[b]	Pronunciation–Reading	Pronunciation–IQ	IQ–Reading[c]
Huegel–3	35	.66**	.51**	.49**
Huegel–6	27	.16	.47*	.77**
Wilson–3	49	.52**	.09	.35*
Wilson–6	65	.46**	.40**	.82**

[a]Correcting for ties made a negligible difference in the correlation value; the figures reported here are uncorrected.

[b]Only *S*s for whom all three scores were available are included in this analysis.

[c]Reading rank was based on the following scores: 3H, Gates-McGinitie Primary C Reading Test; 6H, the reading subtest of the Iowa Tests of Basic Skills; 3W, the word study skills subtest of the Stanford Achievement Test; 6W, the language subtest of the Stanford Achievement Test (the word study skills subtest, more closely related to reading tests, was not given to 6W classes). IQ rank was based on the California Mental Maturity Test for 3H and 6H and the Lorge-Thorndike for 3W and 6W.

*$p < .05$.

**$p < .01$.

Inappropriate Responses

The preceding analyses have dealt with appropriate responses to predictable patterns. Inappropriate responses may be (a) the appropriate pronunciation for that grapheme in a different environment or (b) inappropriate for any environment. The first type of inappropriate response, for instance, might be the pronunciation of *c* in *cerp* as /k/ or /š/—pronunciations of *c* which occur in *cat* and *social*. The second type of inappropriate response, which we shall call "wild," might be the pronunciation of *c* as /m/.

A breakdown of inappropriate pronunciations in this manner showed that, in both the Huegel and Wilson third grades, poor readers gave about twice as many wild pronunciations as good readers; about 25% of the poor readers' inappropriate responses were wild, compared with 10% of the good readers' inappropriate responses.

A curious phenomenon occurring about 10% of the time in both good and poor readers at all grade levels was the pronunciation of the final *-e* marker. A final *-e* is silent whatever its grapheme context in about 99% of all English words. In the graphemic context -VC*e*, where C is a consonant unit, it is pronounced only in the French import *cafe*, or in such low frequency words as *chile*, *Nike*, and *hebe*. Pronunciation of the final *-e* in *cofe* together with shortening of the medial vowel to yield /kɔfi/ (*coffee*) was especially common. Overall, about 30% of the *S*s gave this response.

PRONUNCIATION OF UNPREDICTABLE PATTERNS

Vowel Digraphs

In Table 4 are shown the pronunciation data on vowel digraphs. Under the category "other" are all actual pronunciations occurring less than 10% of the time when averaged over all groups. Two sets of normative indicators of digraph pronunciations are given in the rightmost columns. The first, based on a type count from the 20,000 most frequent English words (Venezky, 1963), indicates the proportion of words containing that digraph which are realized by a particular vowel pronunciation. The second is also a type count indicating relative frequency of particular pronunciations among the 1,000 most frequent words (Thorndike, 1941).

Both type counts are sometimes poor predictors; e.g., the correspondences *ai* → /e/, *au* → /ɔ/, *ou* → /aU/ appear much more infrequently in the data than one would expect on the basis of the type counts. Few readers used the (often false) formula taught in some phonics reading series that the long form of the first vowel in the digraph is the proper pronunciation of the digraph ("When two vowels go walking, the first does the talking," i.e. "says its name"). There was some tendency for better readers to agree on the preferred pronunciation: in 32 of the 42 sets of data in Table 4, the first-ranked pronunciation of the better readers was more frequently chosen than the first-ranked pronunciation of the poor readers. The better readers' preferred pronunciations, however, were not much better predicted by frequency of type occurrence than the poor readers' pronunciations.

There are marked idiosyncratic shifts in pronunciation percentages for digraphs as a function of the context provided by specific synthetic words. Some examples of the context effects are shown in Table 5, together with words which may have mediated the pronunciation. In some instances where predictable letter-sound correspondences of limited generality can be derived (*-ook* → /Uk/ as in *look*, *-oop* → /up/ as in *hoop*), there was a tendency for this pattern to be followed in pronunciation of synthetic words. That the agreement is less than perfect is indicated by the *oo* entries in Table 4: 76% /u/ pronunciations for *-oop* but 37% /U/ pronunciations for *-ook*.

Miscellaneous Comparisons

Final *-s* patterns occurred in two contexts, *thaus* versus *cose* and *clase*. The occurrence of *-s* in terminal position immediately preceded by a vowel or vowel digraph is not frequent, except for plural and possessive pronoun forms (where *-s* is given the voiced form of the fricative /z/) and the common suffix *-ous* (where *-s* is given the voiceless form of the fricative /s/). More typical after a vowel is the spelling *-ss*. The pattern *-se* is not unusual, but both voiced and unvoiced pronunciations are found, as in *rose* versus *dose*. Which pronunciation occurs is not predictable from the graphemic environment. In all groups, *-s* in *thaus* was pronounced /s/ by 90% of the readers, possibly because of its similarity to *this* and *thus*. In *cose*, /s/ and /z/ were observed about equally often,

Table 4. Percentage of Primary Pronunciations of Digraph Vowels

	3H		6H		3W		6W		HSO		CSW		Probability of Type Pronunciation in 20,000 Words	Probability of Type Pronunciation in 1000 Words
	HI	LO	HI	LO	HI	LO	HI	LO	HI	LO	HI	LO		
ai (4)[a]														
/e/	57	33	55	56	47	30	64	29	47	41	75	40	85	71
/ɛ/	17	19	40	17	8	5	17	25	8	8	8	19	1	14
/æ/	20	29	3	17	30	37	15	28	19	27	0	4	1	0
Other	6	19	2	10	15	28	4	18	26	24	15	37	13	15
au (4)														
/ɔ/	49	20	25	27	28	5	26	24	17	19	33	38	92	67
/a/	21	21	50	33	23	22	35	24	50	38	3	10	0	0
/æ/	8	13	0	0	22	24	6	18	0	10	0	0	3	33
Other	22	46	25	40	27	49	33	34	33	33	64[b]	52[b]	5	0
ea (2)														
/i/	86	55	82	77	83	60	91	81	78	82	72	65	61	60
Other	14	47	18	23	17	40	9	19	22	18	28	35	39	40
ee (3)														
/i/	94	70	86	92	86	77	91	85	85	87	74	79	89	97
Other	6	30	14	8	14	23	9	15	15	13	26	21	11	3
ie (3)														
/i/	37	18	38	33	33	16	43	29	56	44	63	59	27	45
/aɪ/	32	32	29	33	23	31	24	26	21	17	11	15	21	33
Other	31	50	33	34	44	53	33	45	23	39	26	26	52	11
oo (3)														
/u/	65	42	67	51	54	37	57	47	40	58	45	59	62	55
/ʊ/	17	21	22	23	11	4	30	21	40	32	26	28	27	40
/o/	11	21	5	14	23	40	3	20	15	10	15	5	3	0
Other	9	16	6	12	12	19	10	12	5	0	14	8	8	5
ou (2)														
/o/	36	26	29	31	21	35	21	32	28	50	--[c]	--	2	5
/u/	14	26	29	15	50	30	41	29	50	35	--	--	6	0
/aʊ/	22	5	25	27	5	2	20	12	9	12	--	--	50	68
Other	28	43	17	27	24	33	18	27	13	3	--	--	42	27

[a] Number of items per comparison.
[b] /aʊ/ in all other cases.
[c] Only one item available.

Table 5. Examples of Shifts in Pronunciation of Vowel Digraphs as a Function of Context

	Item	Potential Mediator	Percentage of Pronunciation	
ou			/u/	/o/
	poup	soup	43	25
	houm	home	33	41
oo			/u/	/ʊ/
	voop	coop	76	14
	yook	look	33	37
ie			/i/	/ɛ/
	mien	mean	45	10
	yiet	yet	22	29
ai			/e/	/ɛ/
	baig	beg	35	42
	kaip	cape	54	11

and in *clase*, /s/ was used about 70% of the time (most often in the form /klæs/, or *class*).

The consonant digraph *th*, when in initial position, has the voiced pronunciation /ð/ only in function words such as *the*, *there*, and *then*, where it is voiced without exception. It is otherwise unvoiced (/θ/), as in *thin* and *thermometer*. Although there are a relatively small number of function words in English by type count, these voiced forms of *th* are from 5 to 50 times more frequent by token count in written and spoken English than the unvoiced form. These function words form a closed set; that is, almost none have been added or lost in the language in the last 400 years. The nonfunction *th* words, on the other hand, form an open-ended class. In the synthetic words ***thaus***, ***theat***, and ***thaid***, the unvoiced form predominated among good (86%) and poor (79%) readers, with no obvious changes over grade levels.

The digraphs *ch* and *gh* in initial position contrast both in frequency of occurrence and regularity of pronunciation. The digraph *ch* is relatively common both by type and token counts. It has one predominant pronunciation, /č/ as in *cheese* and *choose*, but also two variant pronunciations, /k/ as in ***chemical*** and ***chorus*** and /š/ as in ***champagne***. The appropriate pronunciation is not generally predictable from context except for the clusters ***chr*** and ***chl*** in which ***ch*** is pronounced /k/. The digraph *gh*, on the other hand, is completely regular in pronunciation in initial position (/g/ as in ***ghost***) but relatively rare. For both good and poor readers, *ch* was pronounced /č/ 81% of the time; good readers pronounced *gh* as /g/ only 58% of the time, and poor readers gave /g/ only 50% of the time. There was a tendency for both good (10%) and poor (20%) readers at the third- and sixth-grade levels to read *GH* as *GR* (all stimuli were typed in capital letters), which would suggest visual confusions. Good and poor readers gave the pronunciation /ǰ/, as in *gin*, to *ghin* about 30% of the time at all grade levels including college.

RESPONSE TIMES

In Table 6 are shown the response times averaged over all students for each item. In general the latency data were quite variable and gave no evidence of differences associated with grade, school, or reading ability. That there is some consistency of response to particular items is evidenced by the moderate correlations between the two presentation orders, which when calculated for each subgroup ranged from .35 to .45, reliably different from zero ($p < .01$). Correlations computed between groups, using item response times averaged over all subjects in each group, were found to range from .55 to .65. Correlations between good and poor readers within each group ranged from .27 to .55; the correlation between mean time per item for good and poor readers, averaged over all schools and grade levels, was .70. These correlational data indicate that there were reliable differences in response times to different items, and that the larger the number of observations included in any mean response time, the more reliable the differences.

Inspection of Table 6 reveals two possible sources of difference in reaction time. The geminate (double) vowel spellings *oo* and *ee*, whether leading to invariant (*ee*) or variant (*oo*) pronunciations, were pronounced very quickly; at the other extreme were *acol* and *acil*, the only items that were obviously bisyllabic. Response time differences cannot be predicted in a systematic way, however, from difficulty indices drawn from complexity or regularity of LSCs. The more regular vowel digraph patterns are not pronounced faster than the less regular vowel digraph patterns. The predictable patterns (*c*, final *-e*) are not pronounced significantly faster than the unpredictable vowel digraph patterns. Vowel digraphs involving an additional decision about pronunciation of a consonant letter are not pronounced significantly slower than digraphs with consonants whose pronunciation is invariant. Comparing the means of all items involving one choice point for pronunciation (e.g., *dauk*, or *cerp*) with those items involving two choice points (e.g., *theat*, *cipe*) reveals no significant difference.

Table 6. Response Times to Experimental Items, Averaged over All Students

Item	Mean Time (Seconds)	Rank Order
neem	2.45	1
voop	2.53	2
leek	2.56	3
yook	2.58	4
roc	2.77	5
dauk	2.79	6
moch	2.84	7
veeg	2.87	8
cabe	2.90	9
theat	2.92	10
vieb	2.96	11
cune	2.96	12
cose	2.97	13
cerp	3.02	14
mien	3.03	15
laum	3.05	16
clase	3.05	17
chung	3.06	18
thaid	3.10	19
shoog	3.10	20
ghin	3.11	21
peaz	3.15	22
gafe	3.16	23
kaip	3.19	24
kaut	3.20	25
chal	3.21	26
yiet	3.22	27
houm	3.22	28
chait	3.24	29
baig	3.27	30
ghim	3.30	31
cofe	3.30	32
lethe	3.31	33
cipe	3.32	34
thaus	3.36	35
sheip	3.36	36
acol	3.41	37
poup	3.43	38
ghal	3.43	39
acil	3.61	40

IV
DISCUSSION

The present study stems from the project's goal of improving the teaching of beginning reading. For research purposes, we have defined the initial reading process as one of translation from alphabetical symbols to that form of language used by the native speaker in communication (Venezky, Calfee and Chapman, 1968). Since this translation involves sound (or a subvocal representation of sound) as an intermediary to meaning, the formation of LSC generalizations should be an integral part of early reading acquisition. Further, young children identified as good readers should show greater mastery of LSC patterns than poor readers.

The data confirm the expectation of differences in the responses of good and poor readers to the pronunciation task. Good readers are consistently more likely than poor readers to give appropriate responses to predictable patterns; this is true for all ages tested on the final *-e* pattern, and true for the younger readers on *c* patterns. Good readers agree more consistently on a preferred pronunciation for the unpredictable digraph vowels. The youngest good readers studied give only half as many "wild" responses as the poor readers of that age. Good readers show only half as many visual confusions when these can be identified (GR for GH).

It can be said, then, that good readers give more consistent and more appropriate responses to the synthetic words than poor readers. This could be simply a result of general intellectual superiority, or the pronunciation task may tap skills more specifically related to the reading task. There is evidence in our data that, for young children, the pronunciation task is more closely related to reading rank than is IQ. For third graders, pronunciation scores on the final *-e* and *c* before *e* and *i* patterns correlate .66 (3H) and .52 (3W) with reading rank. The comparable correlations of IQ with reading rank are .49 and .35. These pronunciation-reading rank correlations are about as high as the correlations from several studies reported by Chall (1967) between "letter and/or phonics knowledge" and reading achievement. Chall reports substantial correlations at all grades (about .60 to .70), in constrast to the steady decrease in the present study to nonsignificant values in high school.[6]

In the present data, IQ measures are better predictors of reading rank for sixth grade and above than are pronunciation scores. This may indicate that the skills necessary to good performance on reading achievement and IQ tests become increasingly similar as the tests become more advanced. It is interesting to note that when matched in IQ (good Wilson third graders versus poor Huegel third graders), the good readers make the better pronunciation scores.[7] Although the correlation of pronunciation score with reading rank is attenuated at higher grades, readers show increasing mastery of LSCs through high school. Learning continues long after formal reading training is ended. The greatest increment, at least for poor readers, is observed between third and sixth grades. Studies of second-, fourth-, and sixth-grade readers are currently being

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[6]The "letter and/or phonics" tests cited by Chall, however, were much more broadly based than the pronunciation scores used in this study. For older children, both phonics tests and reading tests rely heavily on vocabulary and inference, a fact which may account for the nondecreasing correlations reported by Chall.

[7]The slightly poorer performance of the Wilson third grade is correlated with a variety of confounded factors—socioeconomic level, IQ, number of siblings, and others for which no measures were available (amount of language and reading training at home, peer group characteristics, classroom reading, training, class size). The effect of socioeconomic level, therefore, cannot be determined from this study.

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conducted in an effort to characterize this period of rapid acquisition more completely.

While good and poor readers are differentiated by the appropriateness of their responses to predictable LSC patterns, no grou[illegible] even the oldest and best readers—gi[illegible] appropriate responses all the time. (The case of *c* before *a*, *o*, or *u* is an exception which is best attributed to response bias; /k/ pronunciations of *c* are far more frequent in English.)

The small number of items used to test the final *-e* pattern do not permit a full assessment of either appropriate or inappropriate responses. The items all ended in final *-e*, requiring a long pronunciation of the vowel; there were no items testing for the short pronunciation of the vowel in the same consonant frame. A second characteristic of the final *-e* test items is that they were drawn from -VC*e* spellings which have very few real-word exemplars; that is, there are few words of similar spelling which rhyme with the synthetic items. These items are possibly more difficult, then, than others which might have been chosen (e.g., *tate*, with which at least 20 similarly spelled monosyllabic words rhyme). Unresolved questions include whether different vowel spellings show different rates of mastery, whether the appropriate alternation between long and short vowels is present, and whether partial frames (e.g. -V*te*) affect the appropriateness of vowel pronunciations.

If readers can pronounce patterned synthetic words appropriately part of the time, what do they do with spellings for which no predictable pronunciation exists? The items testing digraph vowel pronunciation yield data on this question. One mode of response is suggested by phonics training programs, which often assert that such patterns should be pronounced with the long form of the leading vowel: "when two vowels go walking, the first one does the talking" and "the first one says its name." This inaccurate generalization is one possible basis for response (only for the digraphs *ai* and *ee* in our list is it true more than 70% of the time); the data clearly indicate, however, that children are not responding in this way.

Two other methods of predicting the distribution of pronunciations were tried. The words containing a particular vowel digraph spelling in the 20,000 most common words were determined (Venezky, 1963), and the percent of those words receiving a particular pronunciation calculated. We then asked whether readers were using a matching or maximizing strategy with respect to this probability distribution of possible pronunciations; that is, whether they produced responses in the same proportion as is found in the 20,000 most common words or whether they always gave the response most frequent in that distribution. The answer seems to be No on both counts. Nor are responses predicted by a similar type count over only the 1,000 most frequent words.

That responses are not necessarily selected from the most probable pronunciations is strikingly exemplified by the high percentage of /au/ responses to *au* from college students. This pronunciation occurs in English only in the German imports *sauerkraut* and *umlaut* (excluding proper names); use of it by college students does not seem to be related to knowledge of German, however. Nor are responses necessarily selected from occurring pronunciations; *au* received many /a/ (as in *top*) pronunciations, which do not occur in English except in dialectal variants. With the exception of *ea* and *ee*, overall agreement on a preferred pronunciation for a vowel digraph was not high; neither was there high agreement on specific items. Shifts in pronunciation of a given digraph as a result of context were observed, however, suggesting that choice of pronunciation may be contextually bound. Whatever the mediating mechanism, the spread of observed pronunciations for most digraph spellings suggests that it tends to be idiosyncratic. That is, the data would fail to support any index which predicted a single pronunciation as the "appropriate" one for a given item.

Latency measures were used as a dependent variable in this experiment on the basis of studies showing that frequency determines latency of word recognition (e.g., Postman and Rosenzweig, 1957). It was surmised that predictable LSCs (i.e., almost invariant LSCs such as the *c* before *e* or *i* patterns) might similarly produce short latencies of pronunciation for synthetic words, whereas unpredictable vowel digraph spellings might be expected to give longer latencies. This expectation was not met. Response-time differences were not related to predictability of pronunciation. Whether visual processing or motoric organization for articulation governed the observed item differences, however, cannot be determined from the data. Both possibilities are suggested; the first by the short latencies for geminate vowel digraphs, the second by the long latencies for obviously bisyllabic items.

In summary, the present data show that to the extent that the child in third grade is judged a competent reader, he has command of some basic LSC patterns. In more advanced grades, the relation between use of these LSC patterns and reading achievement is attenuated, presumably because this ability is only one of many necessary for skilled reading. The data are correlational—we cannot yet say whether instruction leading to acquisition of LSC patterns, by induction or otherwise, would produce good readers. Nor can we state precisely the form of the LSC generalizations used by young readers, or the bases of LSC formation. These questions are currently being explored by studies testing the final -*e*, *c*, and *g* patterns more fully in the second, fourth, and sixth grades.

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GPO 811-841-2