Children's sensitivity to factors influencing vowel reading

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TO DISAMBIGUATE vowel assignment to a vowel digraph in a word, readers must take into account aspects of the word context beyond the vowel digraph units themselves. The present study examined the development of young readers' use of this context in two experiments. First-, third-, and fifth-grade children read aloud high- and low-frequency words containing vowel digraph units with variant and invariant pronunciations (Experiment 1); the third-grade children also read pseudowords containing vowel digraph units with variant pronunciations (Experiment 2). Words and pseudowords containing vowel digraph units with variant pronunciations were further categorized by the uniformity of pronunciation of the vowel digraph-final consonant unit as it appeared in real words (i.e., the orthographic neighborhood consistency). Word reading accuracy of all groups was affected by word frequency and variation in the pronunciation of the vowel digraph unit; however, only the third- and fifth-grade children demonstrated sensitivity to orthographic neighborhood consistency. With the pseudowords, the influence of the vowel digraph-final consonant unit in determining pronunciation was again indicated. The findings from both experiments support the hypothesis that with reading experience, children identify the systematic relationship between pronunciation and orthographic structure and utilize that knowledge in the pronunciation of unfamiliar words.

La sensibilité des enfants aux facteurs influençant la lecture des voyelles

POUR BIEN IDENTIFIER le phonème d'une double voyelle dans un mot anglais, le lecteur doit tenir compte du contexte orthographique en plus de l'orthographe même du groupe de voyelles combinées. A partir de deux expériences, on a pu observer comment se développait l'emploi de ce contexte chez de jeunes élèves. Dans la première expérience, on a demandé à des élèves de première, troisième et cinquième année de lire à haute voix des mots peu fréquents et très fréquents contennant des groupes de voyelles combinées dont la prononciation pouvait être variable ou invariable. Dans la deuxième expérience, les élèves de troisième année ont lu des pseudomots contenant des groupes de voyelles combinées à prononciation variable. De plus, on a classé les mots et les pseudomots présentant des voyelles combinées à prononciation variable selon l'uniformité de la prononciation des unités "voyelles combinées—consonne finale," telles que retrouvées dans des mots réels (cohérence de l'environnement orthographique). L'exactitude de la lecture des mots dépendait, dans tous les groupes, de la fréquence du mot et de la variation dans la prononciation du phonème de voyelles combinées. Toutefois, seuls les élèves de troisième et de cinquième année ont démontré une sensibilité à la cohérence de l'environnement orthographique. L'influence de l'unité "voyelles combinées—consonne finale" s'est également manifestée dans les pseudomots. Les résultats obtenus pour les deux expériences soutiennent l'hypothèse selon laquelle les enfants, grâce à leur expérience de lecture, peuvent établir la relation entre l'orthographe et la prononciation et ainsi déduire la prononciation de mots inconnus.

La sensibilidad de los niños a algunos factores que influencian la lectura de vocales

PARA QUITAR la ambigüedad al asignar un sonido vocálico a una vocal ortográfica en una palabra en inglés, los lectores deben tomar en cuenta aspectos del contexto en la palabra, más allá de la unidad de la grafía vocálica. Este estudio examina el desarrollo del uso de este contexto por lectores jóvenes, por medio de dos experimentos. En el primer experimento, niños de primero, tercero y quinto grado leyeron en voz alta palabras de alta frecuencia y palabras de baja frecuencia que contenían unidades digráficas con pronunciaciones constantes y variantes. En el segundo experimento, niños de tercer año leyeron además pseudo-palabras que contenían unidades digráficas vocálicas con pronunciación variante. Las palabras y pseudo-palabras conteniendo unidades digráficas vocálicas con pronunciación variante fueron a su vez categorizadas por su uniformidad de pronunciación de la unidad digráfica de la consonante final como aparecía en palabras reales (i.e., consistencia por cercanía ortográfica). La exactitud en la lectura de las palabras por todos los grupos se vió afectada tanto por la frecuencia de la palabra como por la variación en la pronunciación de la unidad digráfica vocálica. De todos modos, solamente los niños de tercero y quinto grado mostraron sensibilidad a la consistencia debida a la cercanía ortográfica. Con las pseudo-palabras hubo indicaciones de la influencia de la unidad digráfica de la consonante final. Los hallazgos de ambos experimentos apoyan la hipótesis que dice que con experiencia de lectura, los niños identifican la relación entre pronunciación y estructura ortográfica y que utilizan ese conocimiento en la pronunciación de palabras desconocidas.

Feingefühl bei Kindern Faktoren gegenüber, die das Lesen von Selbstlauten beinflußen

UM ZWISCHEN den Selbstlauten eines Selbstlaut-Digraphs in einem englischen Wort zu unterscheiden, müssen Leser in Erwägung ziehen, daß es Aspekte des Wortzusammenhangs gibt, die über den Digraph hinausgehen. Die vorliegende Studie untersucht mit Hilfe von zwei Experimenten, wie junge Leser lernen können, sich dieses Zusammenhangs zu bedienen. Kinder im ersten, dritten und fünften Schuljahr lasen Worte vor, die oft, und solche, die selten vorkommen, welche Selbstlaut-Digraphen enthalten mit abweichender und nicht-abweichender Aussprache (Experiment 1), und die Dritt-Kläßler lasen dann auch Irr-Worte, welche Selbstlaut-Digraphen mit abweichender Aussprache enthalten (Experiment 2). Worte und Irr-Worte waren ferner bestimmt durch einheitliche Aussprache des letzten Konsonanten im Selbstlaut-Digraph, wie er in tatsächlichen Worten auftaucht (z.B. orthographische Vereinbarkeit innerhalb einer Nachbarschaft). Die Genauigkeit im Wort-Lesen aller Gruppen wurde beeinflußt von der Häufigkeit der Worte und der Unterschiedlichkeit in der Aussprache des Selbstlaut-Digraphs. Allerdings zeigten nur die Kinder im dritten und fünften Schuljahr, daß sie empfänglich waren für orthographische Vereinbarkeit innerhalb von Nachbarschaften. Mit den Irr-Worten wurde erneut die Bedeutung des Letzt-Konsonanten im Selbstlaut-Digraph herausgestellt. Die Resultate beider Experimente unterstützen die Hypothese, daß Kinder, die sich viel im Lesen üben, die Beziehung zwischen Aussprache und orthographischer Struktur erkennen und dieses Verständnis für ihre Aussprache ausnutzen.

Analyses of the errors made by children as they acquire skill in word reading have provided some clues to the problems beginning readers encounter in identifying words. The well-documented finding that, in English, vowel misreadings occur with greater frequency than consonant misreadings (Fowler, Liberman, & Shankweiler, 1977; Shankweiler & Liberman, 1972; Weber, 1970) suggests that beginners in English experience particular difficulty in associating a given orthographic vowel unit with its appropriate pronunciation.

A number of explanations have been proposed to account for the difference in difficulty between vowels and consonants (Fowler, Shankweiler, & Liberman, 1979; Shankweiler & Liberman, 1976). One explanation emphasizes the differences in the linguistic properties of vowels and consonants in speech production and perception, noting that vowels are more fluid and generally less categorically defined than consonants (Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967). Another explanation turns on the difference between vowel and consonant orthography. The preponderance of errors on vowels has been attributed to the fact that the same vowel may be spelled differently in different words. Consonants, on the other hand, have a more nearly one-to-one correspondence between orthographic unit and phonological segment. The consonant letters, with few exceptions, cue the same phonological segments wherever they occur, whereas the letters that represent vowels frequently have multiple phonological referents (Venezky, 1967). Further support for the role of the orthography—rather than the differences between vowel and consonant perception—in accounting for the vowel error pattern is reported by Lukatela and Turvey (1980). In their examination of word reading errors in Serbo-Croatian, an orthography that includes a simple vowel set but a more complex consonant set, phoneme substitutions on medial vowel segments were less frequent than substitutions on initial or final consonant segments.

In view of the complexity of the English vowel orthography, it is hardly surprising that there are more vowel errors than consonant errors in reading English words. In order to disambiguate vowel pronunciation, readers must take into account aspects of the word contexts—the letters surrounding the vowels. Beginners' errors show that they have not yet learned to use the letter context, but instead use grapheme-phoneme correspondences for single vowel letters (Fowler et al., 1979). With age and experience, children narrow the range of vowel renderings with greater and greater precision as they take more account of the surrounding letter contexts (Fowler et al., 1979).

In English, these surrounding letter contexts differ in the extent to which they constrain the selection of the appropriate vowel. The context may be tightly constrained, as in the tense or long pronunciation for orthographic vowel units appearing in the context of the silent *e* marker. Or it may be loosely constrained, as in a vowel digraph that may have several appropriate realizations within a particular context. For example, the vowel digraph *ou* in the context of *gh* may be correctly rendered as /aʊ/ in *bough*, /ʌ/ in *tough*, /ɔ/ in *thought*, /u/ in *through*, or /o/ in *though*. In the studies by Fowler et al., although the stimuli included a wide range of contextual constraints, the possibily differing effects of these contexts were not considered.

Attempts to construct a model for predicting adults' pronunciations of pseudowords containing vowel digraph units (Johnson & Venezky, 1976; Ryder & Pearson, 1980) have suggested that vowel pronunciation could be influenced either by the frequency of occurrence of a unit without regard to the context—that is, without regard to the effect of the final consonant—or, alternatively, by the context provided by the final consonant. Results of those investigations support a model predicting that adult pronunciation is highly determined by frequency of orthographic patterns, but that the functional unit is the vowel digraph-final consonant structure.

Skilled adult readers have in fact been shown to be sensitive to the consistency or inconsistency of the pronunciation of medial vowel-final letter units (Glushko, 1979). Glushko has proposed that, in the course of reading a word, an entire neighborhood of similarly structured words and their pronunciations is automatically activated in memory. Glushko's *neighborhood* includes all monosyllabic words in the reader's lexicon that share the same medial vowel letters in combination with the same letter units in final position. Rhyming words such as *seam*, *beam*, and *team*, sharing both the medial vowel-final letter unit and a uniform pronunciation, would thus constitute a consistent orthographic neighborhood; whereas the words *beat*, *threat*, and *great*, although sharing the medial vowel-final letter unit, fail to share a uni-

form pronunciation, and thus would be classified as constituting an inconsistent orthographic neighborhood. Glushko's adult readers' performance was influenced by the consistency or inconsistency in orthographic neighborhoods as evidenced by more rapid reading and more limited variation in pronunciation of words and pseudowords from consistent orthographic neighborhoods (i.e., words of similar structure sharing a uniform pronunciation), and by a greater latency of response and significant variation in pronunciation of words from inconsistent orthographic neighborhoods (i.e., words of similar structure that fail to share a uniform pronunciation).

The vowel digraph unit in many words may be ambiguous unless the reader can exploit additional cues from the other letters in the word. The broader context—for example, the final consonant—may supply such cues. Whether or not it does could depend on whether word items from an orthographic neighborhood for that vowel digraph-final consonant unit share a consistent pronunciation. Thus, the final consonant might be used to disambiguate the vowel digraph, but its use would involve a complex context-sensitive operation.

A study examining this skill in second-, fourth-, and sixth-grade children (Johnson, 1970) found that the factor most likely to influence children's selections also was the frequency of occurrence of a particular pronunciation for a given unit and, further, that with increasing grade level, children's responses more closely reflected the pronunciations of those units as they appear in real words. Though mention is made of some additional effects of the final consonant context and the position of the vowel digraph unit within the word, Johnson's study was not designed to investigate the influence of consonant context on children's selections as a result of reading experience. Nor did it examine the effects of the frequency of occurrence of the vowel digraph-final consonant structure and the consistency of pronunciation of that structure in real words.

To date, there has been no systematic study of the development of children's use of the final consonant context in disambiguating vowel assignment to vowel digraph units and their sensitivity to orthographic neighborhood consistency. An examination of these effects with children may provide insight into the development of children's awareness of the very complex relationship between the orthography and the phonology. In addition, it would assist us in understanding how normally developing readers use the reading vocabulary they have mastered to develop strategies for identifying unfamiliar words.

In order to explore these questions, we conducted two experiments. The first experiment focused on the development of children's understanding of vowel digraph pronunciation. First-, third-, and fifth-grade children were required to read aloud high- and low-frequency words containing vowel digraph units with variant and invariant pronunciations. For each grade, an examination of error rate and of the characteristics of errors was conducted to explore the effects on word reading accuracy of word frequency, of alternate pronunciations for vowel digraph units, and of consistency of orthographic neighborhood. The second experiment investigated other influences on vowel digraph reading using pseudowords containing vowel digraph units that have variant pronunciations in words. By eliminating the factor of word familiarity, we could study pronunciation preferences for vowel digraph units, as well as factors influencing those pronunciations, and compare the results with those obtained on the real-word reading task.

EXPERIMENT 1

Method

Subjects

The subjects for the first experiment were children from the first-, third-, and fifth-grade classes of a suburban public school system in Connecticut. Basal reading instruction was provided to all students; decoding instruction beyond that included in the reading series was delivered at the teacher's discretion. Following a review of teacher ratings for reading achieve-

ment for the first- and third-grade students, and teacher ratings and group reading achievement test scores for the fifth-grade students, we identified a pool of subjects who were all average or above-average readers. The final population consisted of 90 students, 30 from each grade level.

Procedure

The children were tested individually in two 30-minute sessions during a 3-week period in the Spring of the school year. During the first session, the experimental word reading task was presented. The words had been typed in lowercase, primary type on 4" x 6" (10.16 cm x 15.24 cm) file cards secured in a ring binder. The stimuli were presented in random order with 20 filler words, which were single-syllable items selected from the reading subtest of the Wide Range Achievement Test (Jastak, Bijou, & Jastak, 1978). These filler words were included in order that the randomization satisfy the constraint that words with the same vowel sound not precede one another, thus minimizing possible priming effects. Subjects were instructed to read each word orally and then turn to the following card.

Materials

Two lists of monosyllabic real words were developed, including 68 items in all. One list, as displayed in Table 1, included 16 words containing vowel digraph units with relatively invariant phonological correspondences *ee, oa, oi,* and *ai.* The words in the other list, as displayed in Table 2, included 52 words containing units with variant correspondences *ea, ou, ow, ie,* and *oo.* Words were selected to vary in two respects: frequency and variability of pronunciation of the vowel digraph unit. Frequency was determined by the occurrence of the words in reading material at the third-grade level as indicated in the American Heritage word frequency listings (Carroll, Davies, & Richman, 1971). Classification according to variant or relatively invariant pronunciation was based on the pronunciations reported in a thorough listing (Fischer, 1979) of monosyllabic English words containing vowel digraphs. Both word frequency and variability in pronunciation of the smallest unit—the vowel digraph—were systematically controlled in both stimuli lists.

Table 1 Real-word stimulus items with invariant pronunciations of the vowel digraphs

High-Frequency Words	Low-Frequency Words
green	sleek
street	breed
road	oat
coal	boast
soil	toil
join	joint
paint	ail
main	trait

In addition, as indicated in Table 2, for each monosyllabic word containing a vowel digraph unit with a variant pronunciation, the word's orthographic neighborhood was determined. This determination was made for both high- and low-frequency words. Therefore, within the variant category there were two levels of pronunciation. Levels were determined by the consistency of pronunciation of the larger vowel digraph-final consonant unit as it appeared in real words. Each word with a vowel digraph-final consonant unit that is always pronounced the same way in monosyllabic words sharing that structure was considered to have a consistent orthographic neighborhood. In contrast, each word with a vowel digraph-final consonant unit that is pronounced differently in at least one other monosyllabic word sharing that structure was considered to have an inconsistent orthographic neighborhood.[1]

Results and Discussion

Because the variance in performance was substantially greater for the first-grade than for the third- and fifth-grade students, a separate analysis

Table 2 Real-word stimulus items with variant pronunciations of the vowel digraphs

Consistent Orthographic Neighborhood		Inconsistent Orthographic Neighborhood	
High-Frequency	Low-Frequency	High-Frequency	Low-Frequency
beach	ream	read	tread
clean	dean	speak	steak
		break	teak
		head	plead
young	mount	mouth	youth
found	spout	touch	slouch
group			vouch
proud			soul
tried	fried	owl	flown
piece	niece	how	tow
pie	lied	bowl	jowl
field	shield	low	pow
soon	croon	foot	loot
room	sloop	food	hood
		good	mood
		shoot	soot

was carried out for each grade level. The mean percentages of correct responses, possible pronunciation responses, and error responses for each grade on each word category appear in Tables 3 and 4. The data for each grade were subjected to two separate factorial analyses of variance (ANOVAs). The first analysis examined factors of word frequency and pronunciation variablilty for the vowel digraph unit for the entire set of stimuli. In the second analysis, the factors of word frequency and consistency or inconsistency of the orthographic neighborhood, as determined for the larger vowel digraph-final consonant unit, were examined for the set of words with variant pronunciations.

Effects of Frequency and Vowel Digraph Pronunciation

An ANOVA detected a significant main effect for word frequency for the first-grade, $F(1, 29) = 43.15$, third-grade, $F(1, 29) = 83.29$, and fifth-grade students, $F(1, 29) =$

Table 3 Frequencies and percentages of correct and incorrect responses for real words containing variant vowel digraph units

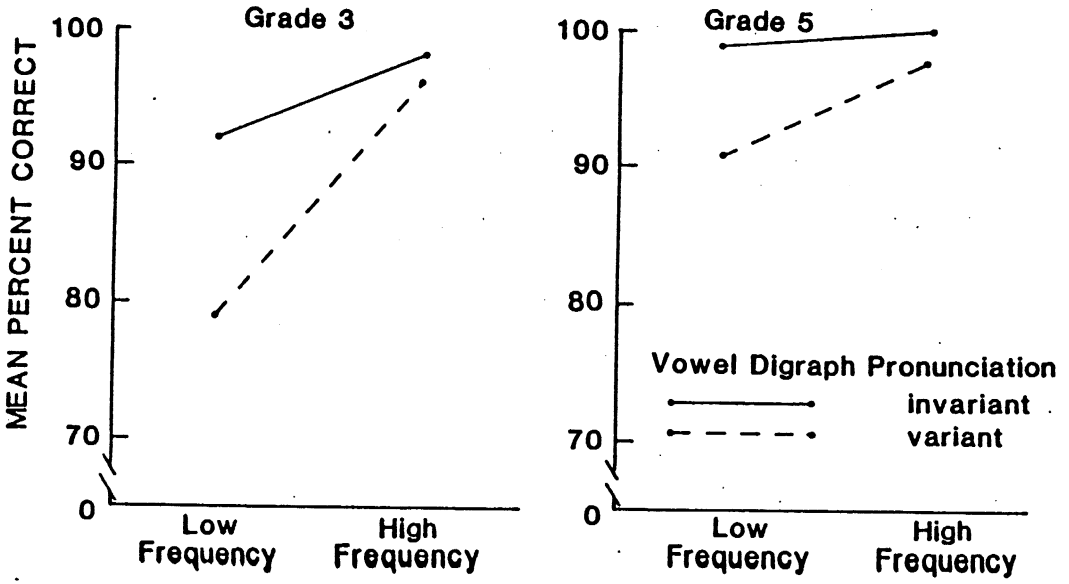
Words	Grade 1		Grade 3		Grade 5	
	Freq.	%	Freq	%	Freq	%
High-Frequency						
Total Correct	509	65	751	96	766	98
Possible Pronunciations	158	20	25	3	14	2
Impossible Pronunciations	113	15	4	1	0	0
Low-Frequency						
Total Correct	332	43	618	79	712	91
Possible Pronunciations	235	30	133	17	57	7
Impossible Pronunciations	213	27	29	4	11	1

Table 4 Frequencies and percentages of correct and incorrect responses for real words containing invariant vowel digraph units

Words	Grade 1		Grade 3		Grade 5	
	Freq.	%	Freq.	%	Freq.	%
High-Frequency						
Total Correct	162	68	237	99	300	100
Errors	78	32	3	1	0	0
Low-Frequency						
Total Correct	130	54	220	92	237	99
Errors	110	46	20	8	3	1

51.97, $p < .0001$ for all. This finding confirms the expectation that children's accuracy in word reading would be favorably enhanced by high word frequency, regardless of the number of alternate pronunciations for the vowel digraph unit contained within these words. As indicated in Tables 3 and 4, accuracy in reading these high-frequency words increased from the first through fifth grades. In addition, a significant main effect for the pronunciation of the vowel digraph unit was obtained for the first-grade, $F(1, 29) = 11.54$, $p < .002$, third-grade, $F(1, 29) = 84.19$, $p < .0001$, and fifth-grade students, $F(1, 29) = 125.54$, $p < .0001$, with words containing invariant vowel digraph units more likely to be read accurately than words containing variant vowel digraph units. As illustrated in Figure 1, an interaction between word frequency and pronunciation for the vowel digraph unit was obtained for the third-grade, $F(1, 29) = 22.70$, and fifth-grade students, $F(1, 29) = 41.03$, $p < .0001$ for both. We interpret this finding as indicating that these older readers had been successful in identifying the systematic relationship between pronunciation and orthographic structure for the words in their

Figure 1
Performance of third- and fifth-grade students on reading low-frequency and high-frequency words, plotted as mean percentage correct



reading vocabularies. Less dependent on previous knowledge of specific words, these older children demonstrated skill in generalizing knowledge of proper pronunciations of invariant vowel digraph units when those units appeared in the context of unfamiliar, low-frequency words.

An examination of error data obtained from the reading of words containing vowel digraph units with variant pronunciations does suggest that a similar generalization is occurring. With increasing grade level of the subjects, the ratio of substitutions of possible alternate pronunciations to errors increased. As indicated in Table 3, at least 50% of the error total for the first-grade students consists of alternate-pronunciation substitutions, and that proportion increases to nearly 90% for the fifth-grade students. Such a finding provides further evidence that as children develop reading skill, they identify the systematic relationships between pronunciation and orthographic structure.

Effects of Frequency and Orthographic Neighborhood Consistency

Results of this ANOVA revealed a significant main effect for frequency for the first-grade, $F(1, 29) = 75.12$, third-grade, $F(1, 29) = 76.79$, and fifth-grade students, $F(1, 29) = 37.47$, $p < .0001$. As indicated in Table 5, once again, word frequency was the most predictive index of word reading accuracy. In addition, a significant main effect for orthographic neighborhood consistency, not found in the analysis of the first-grade data, was obtained for the third-grade, $F(1, 29) = 88.87$, and fifth-grade students, $F(1, 29) = 33.29$, $p < .0001$ for both. As illustrated in Figure 2, a significant interaction occurred between word frequency and orthographic neighborhood consistency for the third-grade, $F(1, 29) = 21.12$, $p < .0001$, and fifth-grade students, $F(1, 29) = 9.64$, $p < .0042$. When low-frequency words were presented, those words from consistent orthographic neighborhoods were read with accuracy

Figure 2
Performance of third- and fifth-grade students on reading low-frequency and high-frequency words with variant vowel digraph units, plotted as mean percentage correct

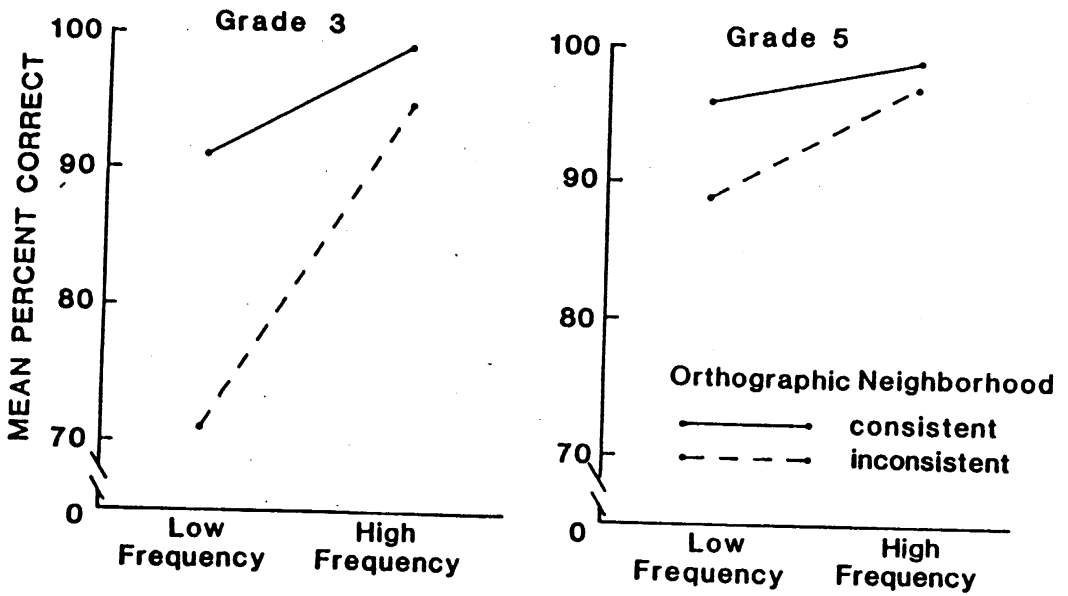


Table 5 Mean percentages of correct responses for high- and low-frequency words containing variant vowel digraph units from consistent and inconsistent orthographic neighborhoods

	Orthographic Neighborhood					
	Consistent			Inconsistent		
Words	Grade 1	Grade 3	Grade 5	Grade 1	Grade 3	Grade 5
High-Frequency % Correct	62	98	99	68	95	97
Low-Frequency % Correct	44	91	96	42	72	89

Note. $n = 30$ for each grade.

comparable to that obtained for the high-frequency words. This result suggests that the older readers have developed a reading vocabulary sufficient to provide a data base from which to determine the relations between orthographic structure and pronunciation. Such analysis of interword relations and awareness of consistencies and inconsistencies between orthographic structure and pronunciation—in this case, the vowel digraph-final consonant structure—provide the reader with the knowledge necessary to pronounce an unfamiliar word correctly.

EXPERIMENT 2

The results of Experiment 1 provide evidence that older readers' accuracy and error rate in reading real words containing vowel digraph units with variant pronunciations are influenced by the consistency of pronunciation of other words sharing the particular vowel digraph-final consonant unit. To examine this effect further and to begin exploring the effect of the initial consonant-vowel digraph unit on pronunciation selection, we conducted a second experiment. In this experiment, the third-grade children who had participated in the first experiment were asked to read monosyllabic pseudowords containing vowel digraph units with variant pronunciations. By eliminating the possibility of word familiarity, we anticipated that factors influencing reading would be more clearly revealed.

Method

Subjects

The subjects participating in the second experiment were the 30 third-grade children who had participated in Experiment 1. All subjects selected were native English speakers with no known hearing or vision impairments.

Procedure

Approximately two weeks after the session described in Experiment 1, a second session was held for the third-grade children, during which the experimental pseudoword reading task was presented. The words were again presented on file cards in a ring binder. Subjects were informed that the words were nonsense or "pretend" words, and that they should not attempt to make real words out of the items. They were instructed to read each word orally and to turn to the following card after reading each word. All pronunciations were recorded on tape for later transcription and analysis.

Materials

A list of 60 monosyllabic pseudowords was developed that contained vowel digraph units with variant pronunciations *ea, oo, ou, ow,* and *ie.* Each pseudoword consisted of initial and final segments that might appear in real words. The initial consonant-vowel digraph segment and the vowel digraph-final consonant segment in each of the pseudowords represented a legitimate sequence in English phonology. However,

vowel digraph segments in the pseudowords might have different pronunciations in different real-word contexts. For example, the *ou* unit in the pseudoword *moung* might be rendered like the *ou* in *mouth* or the *ou* in *young*. Each pseudoword constructed in this manner was reviewed to determine the consistency of pronunciation among monosyllabic real words sharing the pseudoword's vowel digraph-final consonant unit. Of the 60 items, 36 pseudowords were determined to have consistent orthographic neighborhoods, as evidenced by the uniformity of pronunciation among monosyllabic real words sharing those particular vowel digraph-final consonant structures (Fischer, 1979). The remaining 24 items were determined to have inconsistent orthographic neighborhoods by the lack of uniformity of pronunciation among monosyllabic real words sharing those particular vowel digraph-final consonant structures (Fischer, 1979). The final pseudoword lists are included in Tables 6 and 7.

Results and Discussion

The pronunciation preferences of the 30 third-grade students for reading each of the pseudowords are listed as percentages in Tables 6 and 7. Vowel digraph-final consonant units that were determined to have consistent orthographic neighborhoods because of their uniform pronunciation in monosyllabic real words are listed in Table 6. Items determined to have inconsistent orthographic neighborhoods appear in Table 7.

Influence of the Vowel Digraph-Final Consonant Unit

It is evident from Tables 6 and 7 that pronunciations for pseudowords containing the vowel digraph units *oo* and *ea* tended to vary with the consistency of their orthographic neighborhood. Pseudoword units *-ooth*, *-oom*, *-oon*, and *-each*, *-ean*, and *-eam*, all considered

Table 6 Percentages of total responses to each pseudoword item from consistent neighborhood by vowel digraph pronunciation

Pseudoword	Pronunciation				Other Responses or Errors
	/u/	/ʊ/			
mooth	90	0			10
looth	94	3			3
troom	97	3			0
poom	94	3			3
shoon	90	3			3
smoon	100	0			7
woon	93	0			0
					7
	/i/	/eɪ/	/ɛ/		
meach	94	3	0		3
slean	97	0	3		0
chean	97	0	0		3
team	94	3	0		3
	/u/	/o/	/aʊ/	/ʌ/	
cloup	30	13	37	3	17
noup	73	20	7	0	0
proup	50	17	30	0	3
moung	3	0	20	70	7
groung	0	10	50	37	3
moud	13	20	64	0	3
gound	0	3	87	3	7
yound	7	0	67	23	3
	/i/	/aɪ/			
kie	17	83			0
nie	7	93			0
chie	43	57			0
bries	27	70			3
fied	47	50			3
fiels	60	37			3
mield	47	40			13
pield	67	27			6
lield	60	27			13
shief	67	17			17
drief	67	33			0
tiece	57	40			3
criece	60	40			0
biece	60	37			3
fiece	70	27			3

Note. $N = 30$.

Table 7 Percentages of total responses to each pseudoword item from inconsistent orthographic neighborhoods by vowel digraph pronunciation

Pseudoword	Pronunciation				Other Responses or Errors
	/u/	/ʊ/			
bool	80	7			13
smood	97	3			0
tood	73	17			10
zook	54	43			3
mook	50	47			3
	/i/	/eɪ/	/ɛ/		
stread	60	0	40		0
clead	80	0	17		3
chead	77	0	23		0
steat	97	0	3		0
preat	90	3	3		3
dreak	70	13	10		7
heak	94	0	3		3
treak	94	0	3		3
	/u/	/o/	/aʊ/	/ʌ/	
touth	30	17	43	3	7
mouch	0	7	80	13	0
fouth	7	10	60	0	23
	/aʊ/	/o/			
blowl	53	47			0
lowl	37	60			3
snowl	37	63			0
fow	57	43			0
clow	80	17			3
drow	43	47			10
cown	100	0			0
hown	97	3			0

Note. $N = 30$.

to have consistent orthographic neighborhoods, were usually pronounced as /u/ for the former and /i/ for the latter. These pronunciations occurred in at least 90% of the cases. In contrast, the units *-ool*, *-ood*, *-ook*, and *-ead*, *-eat*, and *-eak*, all considered to have inconsistent orthographic neighborhoods, were the source of considerable variation in pronunciation. The *oo* unit in pseudowords received the /u/ pronunciation in 50% to 97% of the cases; the *ea* unit received the /i/ pronunciation in 60% to 97% of the cases.

Certain units elicited the greatest variation in pronunciation. For example, the pronunciations for the unit *oo* followed by *k* were evenly distributed between /u/ and /ʊ/. For each of these items, the initial word segments *moo-* and *zoo-* were words likely to be in a third-grade child's reading vocabulary. However, the highly frequent words *book* and *look*, also likely to be in a young child's reading vocabulary, provide the child access to the dominant pronunciation for the unit *-ook* as it appears in monosyllabic real words. These factors, in addition to these items' inconsistent orthographic neighborhood, may account for the great variation in the pronunciation.

Influence of the Initial Consonant-Vowel Digraph Unit

In contrast to the even distribution of pronunciation selections for both pseudoword items ending in *-ook* is the inconsistency in assignment of pronunciation to several other pseudoword items containing identical vowel digraph-final consonant structures. For example, similar variation in pronunciation might be expected for the three items ending in *-ead*, a unit with an inconsistent orthographic neighborhood. Instead, the *ea* unit in the pseudoword *clead* was rendered as /i/ 80% of the time; whereas in the item *stread*, it was similarly rendered only 60% of the time. It seems likely that real words sharing the initial consonant-vowel digraph structure may have been biasing the pronunciation of the pseudoword, but a final determination must await further study.

As indicated in Table 6, the consistency of pronunciation expected for the *ou* unit in pseudowords ending in *-oup*, *-oud*, and *-ound*, considered to have consistent neighborhoods and expected to be rendered as /u/, /aʊ/, and /ɑʊ/, respectively, was not obtained. It may be that the paucity of words ending in those struc-

tures in a third-grade child's reading vocabulary reduced the saliency of the vowel digraph-final consonant unit, allowing the initial word segment to influence pronunciation. For example, the pseudowords *proup* and *cloup* were expected to be rendered on the basis of the reader's knowledge of words such as *soup* and *group*. Instead, the *ou* unit was frequently rendered as /aʊ/. As an explanation of that result, we would suggest that words such as *proud* and *cloud*, which share the exact initial consonant-vowel digraph unit with *proup* and *cloup*, may have been activated and contributed to the unexpected pronunciation.

In view of that result, the apparent saliency of the /ʌ/ pronunciation for the *ou* unit in *moung* is particularly notable. Though that pronunciation occurs in English only in the single word *young*, the *ou* unit embedded in the pseudoword *moung* received the /ʌ/ pronunciation 70% of the time, despite membership of the initial segment in a neighborhood containing *mouth* and *mountain*. In contrast, the other pseudoword item containing the *-oung* unit, *groung*, received the /ʌ/ pronunciation only 37% of the time, and the pronunciation /aʊ/, associated with the initial segment *grou-*, 50% of the time.

Mixed Influence

Additional evidence for the possibility that pronunciation selections could be influenced by the initial consonant-vowel digraph unit was revealed in the analysis of the *ow* unit in pseudowords. Any pseudoword containing the *ow* unit, whether it ended a word or was combined with *l* as in *-owl* or *n* as in *-own*, was considered to have an inconsistent orthographic neighborhood. Pronunciations of pseudowords containing the *ow* unit reflected that inconsistency, with the exception of the *ow* in the items *cown* and *hown*. The *ow* unit in these words was rendered as /aʊ/ in 100% and 97% of the cases, respectively. In each of these instances, the initial word segment consisted of a morpheme, the pronunciation of which was not overridden by the pronunciation inconsistency of the final unit *-own*. In addition, words likely to be present in a third-grade child's reading vocabulary—*down*, *brown*, and *town*—provide identical pronunciations for the *ow* unit and share the *-own* structure, probably accounting for the consistent rendering of these items.

Pseudowords containing the vowel digraph unit *ie* were all expected to reflect their consistent orthographic neighborhoods. The designation of consistency was based, as always, on the uniformity of rendering of the vowel digraph-final consonant unit in similarly structured real words. However, in the case of pseudowords containing the *ie* unit, the detection of neighborhood consistency required that the reader respond to the affixation of plural and past tense markers as a signal for the /aɪ/ pronunciation. The third-grade readers in this study were able to identify the *ie* unit in the pseudoword items *kie* and *nie as* /aɪ/, *yet their pronunciations for similar items with the plural or past tense marker were variable. For example, the ie* unit in the items *bries* and *fied* received the /aɪ/ pronunciation in only 50% to 70% of the cases.

The *ie* unit in pseudowords ending in *-ield*, *-iece*, and *-ief* was expected to be pronounced as /i/, on the basis of knowledge of such words as *field*, *piece*, and *chief*. A review of the responses indicates that items ending in these units received the /i/ pronunciation in 47% to 70% of the cases. Evidently, pronunciation preferences were influenced by experience or instruction, but the design of the stimuli did not allow us to pinpoint the source of the variation in pronunciation of the *ie* unit in that context.

GENERAL DISCUSSION

We examined children's acquisition of word reading skills with particular emphasis on the development of young readers' responses to variant vs. invariant phonologic associations for vowel digraph units, the use of the final consonant context in disambiguating vowel assignment to invariant vowel digraph units, and children's sensitivity to the orthographic neighborhood consistency of that vowel digraph-final consonant structure.

In the data obtained in Experiment 1, the word reading accuracy of the first-grade chil-

dren was strongly affected by word frequency. This finding supports the view expressed by Gough and Hillinger (1980) that initial acquisition of word reading skills may typically be accomplished through rote learning with the result that frequently encountered words are usually identified without analysis of word components.

The word reading accuracy of third- and fifth-grade students was also affected by word frequency, but in addition, the older readers read low-frequency words containing vowel digraph units with invariant pronunciations with accuracy comparable to that obtained for the high-frequency words. This effect is consistent with results of earlier studies (Fowler et al., 1979; Venezky & Johnson, 1973; Venezky & Massaro, 1979) demonstrating children's ability to generalize knowledge of orthographic patterns beyond the words in which they were originally encountered. In contrast, low-frequency words containing vowel digraph units with variant pronunciations were a significant source of error even for the older readers.

When these low-frequency words were further categorized by consistency or inconsistency of their orthographic neighborhoods, those from consistent orthographic neighborhoods were read by the third- and fifth-grade students with a level of accuracy close to that obtained for both high-frequency words and those of low frequency that contained invariant vowel digraph units. For the children in the higher grades, only the low-frequency words containing variant vowel digraph units with inconsistent orthographic neighborhoods were a substantial source of error. These results provide support for a model in which the final consonant predicts vowel digraph pronunciation preferences (Johnson & Venezky, 1976; Ryder & Pearson, 1980). The results also support the hypothesis (Glushko, 1979) that the ability to read the vowel in words is affected by the consistency of pronunciation of words sharing a particular medial vowel-final letter unit. Despite some exceptions, these findings speak to the special salience of the vowel digraph-final consonant unit in disambiguating vowel pronunciation.

In the second experiment, pseudoword stimulus items were used to allow us to explore further the influence of the neighboring orthographic segments on vowel pronunciation. The results of Experiment 2 provide support for the influence of the vowel digraph-final consonant unit in determining the rendering of the vowel in English-like pseudowords. The influence of this unit could be seen in the greater uniformity of the pronunciation of pseudowords ending in particular vowel digraph-final consonant units from consistent orthographic neighborhoods. In instances where there was less uniformity in pronunciation of such items, the influence of the initial segment appears to account for most of the variability. This result was observed for the items *proup* and *cloup*, in which the *ou* unit was frequently pronounced as /aʊ/ despite the consistency of pronunciation evidenced by the *-oup* unit as it appears in real words. Many of these exceptions can be rationalized if one considers possible interference from initial consonant-vowel digraph occurrences in familiar real words. These cases suggest that, in future work, it will be desirable to expand the concept of neighborhood consistency to examine influences from the initial portion of the word as well as from the final.

One possible explanation for the results is the operation of a left-to-right letter-string parser (Marcel, 1980). Marcel proposed that when a word or pseudoword is presented to a reader, the letter string is segmented in all possible ways. Each word segment, as it is parsed, automatically activates the pronunciations of that unit as it occurs in different words. Thus, for the young reader the pronunciation activated for the word segments *prou-* and *clou-* may result from the words *proud* and *cloud* in their reading vocabularies. Word pronunciation may result from the parsing of successive units of the letter string, during which the pronunciation of later-appearing segments may override the pronunciation of prior segments (Baron & Strawson, 1976; Marcel, 1980). For the young reader, then, it may be that the strength of the association between the unit *ou* and the /aʊ/ pronunciation was too strong to be overridden by the pronunciation of *-oup* as it appears in the words *soup* and *group*.

The proposal put forth by Marcel (1980) also explains the pronunciation of the *ou* unit in the item *moung* as /ʌ/. According to Marcel's explanation, as a child attempts pronunciation of the pseudoword *moung*, the initial segment parsed is *mou-*, the *ou* unit likely to be pronounced as /aʊ/ on the basis of knowledge of words such as *mouth* and *mountain*. When the child parses the final segment of the letter string *-oung*, however, a different pronunciation for that unit is activated on the basis of the occurrence of that unit in the word *young*. As it happened, the pronunciation of the *ou* unit in the pseudoword *moung* was frequently /ʌ/, attesting to the strong effect the final word segment seems to maintain over word pronunciation.

A left-to-right parser, with capacity to override and disambiguate pronunciations activated for earlier segments of a word, would require that the reader have a substantial reading vocabulary and awareness of the phonemic segmentation of the words in the lexicon. It has been well documented not only that phonemic awareness is a predictor of reading achievement (Blachman, 1983; Bradley & Bryant, 1983; Bryant & Bradley, 1980; Liberman, 1973; Lundberg, Olofsson, & Wall, 1980), but also that this awareness is enhanced by reading experience and instruction (Liberman, Liberman, Mattingly, & Shankweiler, 1980; Morais, Cary, Alegria, & Bertelson, 1979). We may speculate, therefore, that the limited reading vocabularies of most first-grade students, in combination with their underdeveloped phonemic awareness and segmenting skills, effectively limit the amount of information that they are able to utilize in reading new words. As a result, the first-grade children were more likely to identify high-frequency words correctly than low-frequency words, regardless of the number of alternate pronunciations for the vowel digraph. Insensitive to orthographic neighborhood consistency or inconsistency, the first-grade readers were unable to use the larger vowel digraph-final consonant context to disambiguate vowel assignment to a vowel digraph.

We must ask whether this result may be an artifact of instruction. All children participating in this study had received what is best identified as an eclectic approach to reading instruction. As reported, the third-grade and—even more so—the fifth-grade students had developed a sensitivity to orthographic neighborhood consistency, taking account of the wider vowel digraph-final consonant context to disambiguate vowel assignment to a vowel digraph. Apparently, by the third grade, children who are progressing normally in reading have acquired a corpus of words in their reading vocabularies adequate to meet the demands of an operation that requires phoneme awareness, segmenting skill, and prior word knowledge to determine the pronunciation of an unfamiliar word. In contrast, first-grade students, as they learn new words, are just beginning to identify the phoneme correspondences of individual graphemes and may depend heavily on these to identify vowel digraphs. Thus, their responses, though incorrect, include some substitutions that are possible in certain other contexts.

This difference between the performances of the first- and third-grade students raises critical questions for future investigation. We are interested to know whether, during that second year of formal reading instruction, children merely acquire a more extensive reading vocabulary in a rote manner, or whether they begin then to analyze interword relations, identifying consistencies between orthographic structures larger than the individual letters and their pronunciation. Moreover, we should like to know whether different methods of instruction will make a difference in the development of these skills, and even whether there may be lasting effects of such instructional differences. In addition, our attention must turn to those older children who fail to acquire automatic word-reading skills. Are these older, poorer readers functioning like the first-grade readers, or are they utilizing different information to determine the pronunciation of an unfamiliar word? The answers to these questions will further our understanding of reading and of how it develops.

REFERENCES

BARON, J., & STRAWSON, C. (1976). Use of orthographic and word-specific knowledge in reading words aloud. *Journal of Experimental Psychology: Human Perception and Performance, 2,* 386-393.

BLACHMAN, B. (1983). Are we assessing the linguistic factors critical in early reading? *Annals of Dyslexia, 33,* 91-109.

BRADLEY, L., & BRYANT, P.E. (1983). Categorizing sounds and learning to read—A causal connection. *Nature, 301,* 419-421.

BRYANT, P.E., & BRADLEY, L. (1980). Why children sometimes write words which they cannot read. In U. Frith (Ed.), *Cognitive processes in spelling* (pp. 355-370). London: Academic Press.

CARROLL, J.B., DAVIES, P., & RICHMAN, B. (1971). *Word frequency book.* New York: American Heritage.

FISCHER, P.E. (1979). *Words according to the GFB sequence for teaching and testing reading.* (Available from Dr. Phyllis E. Fischer, Department of Special Education, Southern Connecticut State University, New Haven, Connecticut.)

FOWLER, C.A., LIBERMAN, I.Y., & SHANKWEILER, D. (1977). On interpreting the error pattern of the beginning reader. *Language and Speech, 20,* 162-173.

FOWLER, C.A., SHANKWEILER, D., & LIBERMAN, I.Y. (1979). Apprehending spelling patterns for vowels: A developmental study. *Language and Speech, 22,* 243-252.

GLUSHKO, R.J. (1979). The organization and activation of orthographic knowledge in reading aloud. *Journal of Experimental Psychology: Human Perception and Performance, 5,* 674-691.

GOUGH, P.B., & HILLINGER, M.L. (1980). Learning to read: An unnatural act. *Bulletin of the Orton Society, 30,* 179-196.

JASTAK, J.F., BIJOU, S.W., & JASTAK, S.R. (1978). *Wide range achievement test.* Wilmington, DE: Jastak Associates.

JOHNSON, D.D. (1970). *Factors related to the pronunciation of vowel clusters* (Tech. Rep. No. 149). Madison: University of Wisconsin, Research and Development Center for Cognitive Learning.

JOHNSON, D.D., & VENEZKY, R.L. (1976). Models for predicting how adults pronounce vowel digraph spellings in unfamiliar words. *Visible Language, 10,* 257-268.

LIBERMAN, A.M., COOPER, F.S., SHANKWEILER, D.P., & STUDDERT-KENNEDY, M. (1967). Perception of the speech code. *Psychological Review, 74,* 431-461.

LIBERMAN, I.Y. (1973). Segmentation of the spoken word and reading acquisition. *Bulletin of the Orton Society, 23,* 65-77.

LIBERMAN, I.Y., LIBERMAN, A.M., MATTINGLY, I.G., & SHANKWEILER, D. (1980). Orthography and the beginning reader. In J.F. Kavanagh & R. Venezky (Eds.), *Orthography, reading and dyslexia.* Baltimore, MD: University Park Press.

LUKATELA, G., & TURVEY, M. (1980). Some experiments on the Roman and Cyrillic alphabets of Serbo-Croatian. In J.F. Kavanagh & R.L. Venezky (Eds.), *Orthography, reading and dyslexia.* Baltimore, MD: University Park Press.

LUNDBERG, I., OLOFSSON, A., & WALL, S. (1980). Reading and spelling skills in the first school years, predicted from phonemic awareness skills in kindergarten. *Scandinavian Journal of Psychology, 21,* 159-173.

MARCEL, A.J. (1980). Surface dyslexia and beginning reading: A revised hypothesis of the pronunciation of print and its impairments. In M. Coltheart, K. Patterson, & J. Marshall (Eds.), *Deep dyslexia.* London: Routledge & Kegan Paul.

MORAIS, J., CARY, L., ALEGRIA, J., & BERTELSON, P. (1979). Does awareness of speech as a sequence of phones arise spontaneously? *Cognition 7,* 323, 331.

RYDER, R.J., & PEARSON, D.D. (1980). Influence of type-token frequencies and final consonants on adults' internalization of vowel digraphs. *Journal of Educational Psychology, 72,* 618-624.

SHANKWEILER, D., & LIBERMAN, I.Y. (1972). Misreading: A search for causes. In J.F. Kavanagh & I.G. Mattingly (Eds.), *Language by ear and by eye: The relationships between speech and reading.* Cambridge, MA: Massachusetts Institute of Technology Press.

SHANKWEILER, D., & LIBERMAN, I.Y. (1976). Exploring the relations between reading and speech. In R.M. Knights & D.J. Bakker (Eds.), *The neuropsychology of learning disorders: Theoretical approaches.* Baltimore, MD: University Park Press.

VENEZKY, R.L. (1967). English orthography: Its graphical structure and its relation to sound. *Reading Research Quarterly, 2,* 75-105.

VENEZKY, R.L., & JOHNSON, D.D. (1973). Development of two letter-sound patterns in Grades One through Three. *Journal of Experimental Psychology, 64,* 109-115.

VENEZKY, R.L., & MASSARO, D.W. (1979). The role of orthographic regularities in word recognition. In L.B. Resnick & P.A. Weaver (Eds.), *Theory and practice of early reading* (Vol. 1, pp. 85-107). Hillsdale, NJ: Erlbaum.

WEBER, R. (1970). A linguistic analysis of first-grade reading errors. *Reading Research Quarterly, 5,* 427-451.

Footnotes

This paper was presented at the 1984 AERA Convention of the American Educational Research Association, New Orleans, April, 1984. The authors would like to thank Arnold Fassler, Director, Special Education Resource Center, Hartford, Connecticut, for enlisting the support of the Bloomfield, Connecticut, public school system; and Herb Chester, Superintendent, Art Matiello, Director of Reading Services, and the reading consultants, faculty, and children of the Bloomfield, Connecticut, public school system for their cooperation in this study. This research was supported in part by a grant from the University of Connecticut Research Foundation to the senior author and by NICHD Grant HD-01994 to the Haskins Laboratories.

[1]The listing developed by Fischer (1979) is composed of single-syllable words which are organized by the word structure (i.e., the pattern of vowels and consonants appear-

ing in the word). One of these word sets includes words which contain the vowel digraph units utilized in this study. Fischer has further organized this list by the vowel digraph unit, and words containing a specific vowel digraph appear together. To develop the word sets utilized in this study, Fischer's list was further organized by the variability in pronunciation of the vowel digraph unit as it appears in single-syllable words. Two word categories were identified: words containing variant vowel digraph units (*ea*, *ou*, *ow*, *ie*, *oo*) and those words containing relatively invariant vowel digraph units (*ee*, *oa*, *oi*, and *ai*). Those words containing a vowel digraph unit with a variant pronunciation were again divided into listings according to the vowel digraph-final consonant unit. These listings were further organized by the consistency of pronunciation of the vowel digraph-final consonant unit as it appears in single-syllable words. Given the organization of this list, the consistency or inconsistency of a word's orthographic neighborhood is clearly indicated.