

1217

# Identification of Vowel Speech Sounds by Skilled and Less Skilled Readers and the Relation with Vowel Spelling

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*Reading and spelling errors of vowels are reported in many studies (Bryson and Werker 1989; Fowler, Liberman, and Shankweiler 1977; Fowler, Shankweiler, and Liberman 1979; Goswami 1993; Landerl, Wimmer, and Frith 1997; Shankweiler and Liberman 1972). The present study tested the hypothesis that spelling errors involving vowels*

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*are linked to difficulties in vowel perception. Second to fourth graders (total n = 155) were divided into five groups according to reading skill and were tested on a variety of measures involving vowel identification, vowel discrimination, and vowel spelling. Despite little difficulty on the vowel discrimination tasks, participants made many errors on the vowel identification measures. Vowel identification errors were linearly associated with reading skill with least skilled readers having significantly more difficulty with stressed "short" vowels as in dip than with stressed "long" vowels as in deep, presented in identical contexts. Vowel identification errors were also associated with vowel spelling errors. It is hypothesized that errors in vowel spelling may relate to weak access to the phoneme at the oral language level and may indicate a lack of constancy in the representation of vowels by less skilled readers. Weaknesses in vowel perception can be detected with a simple vowel identification test in which phonological similarity of test items is used as linguistic manipulation, and where phonemes must be identified based on presentation of a single test item in a forced choice format.*

## INTRODUCTION

Reading and spelling are dependent on phonological processing of speech sounds and syllables. The obligatory nature of phonological processing in reading has been demonstrated for alphabetic orthographies (Berent and Perfetti 1995; Van Orden, Pennington, and Stone 1990), for orthographies that use partially overlapping alphabets (Lukatela and Turvey 1998), and for logographic writing systems (Perfetti and Zhang 1995; Tan, Hoosain, and Siok 1996) (see Coltheart 1978 for a different view). However, the phonological processing necessary for reading and spelling appears not to be as immediate or precise in persons who manifest reading and spelling disabilities (e.g., Rubin and Liberman 1983). Such persons show deficits in phonemic awareness (Bradley and Bryant 1978; Lundberg, Olofsson, and Wall 1980; Morais 1987) and in underlying perceptual abilities (Brady 1997; Fowler 1991; McBride-Chang 1995) such as discrimination of speech sounds (Godfrey, Syrdal-Lasky, Millay, and Knox 1981; Kraus et al. 1996; Reed 1989). They also have difficulties with pronunciation (Apthorp 1995; Lieberman et al. 1985), and show slow access to the lexicon (Bowers and Wolf 1993). If the underlying linguistic ability to discriminate speech sounds is directly linked to reading and spelling acquisition, it is important to determine which linguistic segments are perceived less accurately by children with

reading and spelling problems, in what context a segment is less well perceived, and what the consequences are for the spelling of these segments.

## READING AND SPELLING ACCURACY OF VOWELS

Many reading and spelling studies have noted that readers have difficulties with vowels (Bryson and Werker 1989; Fowler, Liberman, and Shankweiler 1977; Fowler, Shankweiler, and Liberman 1979; Goswami 1993; Landerl, Wimmer, and Frith 1997; Shankweiler and Liberman 1972). In the study by Shankweiler and Liberman (1972) vowel reading errors were twice as frequent as initial and final consonant reading errors combined, whereas almost no vowel errors were made in oral speech repetition. Vowels were equally difficult to read in initial, medial, and final position in one-syllable words (Fowler, Liberman, and Shankweiler 1977), independent of word or non-word status (Fowler, Shankweiler, and Liberman 1979). In a reading study by Ehri, Wilce, and Taylor (1987), children had difficulty with the categorization of the short vowel in CVC<sup>1</sup> words, especially when the following consonant was the velar stop consonant /g/ or /k/.

The fact that readers in English show more difficulties with the reading and spelling of vowels than consonants could be an artifact of the consistency with which the vowel is spelled in English (Berndt, D'Autrechy, and Reggia 1994). German is considered to be a language possessing the same word roots as English but with a more consistent orthography. In a study in which German words, English words, and pseudowords were equated, English children made many vowel errors and misread real words for pseudowords, whereas the German children did not make such errors (Frith, Wimmer, and Landerl 1998).

Although variations in orthographic regularity affect how fast children become aware of the phonological idiosyncrasies in their language (Wolf et al. 1994; Zinna, Liberman, and Shankweiler 1986), vowel reading and spelling errors also occur in some orthographically consistent languages such as Finnish. Finnish persons with a reading impairment show a particular difficulty in mapping letters onto (phonetically) short and long vowels (Lyytinen et al. 1995) in consistently spelled words.

<sup>1</sup>Here and elsewhere, CVC refers to Consonant-Vowel-Consonant; CV for Consonant-Vowel, etc.

Hence, difficulties with reading English vowels may reflect more than the fact that there are many possible spelling mappings for any given vowel phoneme.

Why is it so difficult for less skilled readers of English to remember the accurate spelling of vowels? Writing in an alphabetic orthography does not merely transcribe speech sounds. It reveals the underlying speech structure and forces the writer into conscious awareness of the relation between speech sounds and written symbols. As expressed by Olson (1996), "to learn to read any script is, at base, to find or detect aspects of one's own implicit linguistic structure that can map onto or be represented by elements of that script" (p. 93). In addition, Olson (1996) stresses that "such awareness is not just implicit linguistic knowledge brought to consciousness but rather a matter of sorting sounds into the categories provided by the script" (p. 95). If, as this view suggests, learning to read in an alphabetic writing system requires the discovery of language structure, the errors in reading or spelling vowels may imply a more fundamental underlying oral language deficit with respect to vowels.

#### THE PERCEPTION OF VOWELS

Deficits in perceiving vowels have only been observed in persons with reading deficits when natural speech is altered in some way (Aphorpe 1995; Brady, Shankweiler, and Mann 1983; Bryson and Werker 1989; Lieberman et al. 1985). For example, in the Lieberman et al. (1985) study, adult dyslexics had so much difficulty when asked to repeat synthesized vowels varying only in formant frequency that they were retested, with the same results. Despite such reports, there has been little follow-up research on the perception of vowels among persons with reading deficits.

In order to assign a speech sound to a phoneme, the relational properties of speech segments must be taken into account because phonemes are realized differently, depending on position in the word (Jakobson and Halle 1968) and on surrounding phonemes (Denes and Pinson 1963). To cite just one example, English vowels are lengthened dramatically before voiced stop consonants. According to Chen (1970), in CVC words, vowel duration of the /ā/<sup>2</sup> before the voiceless /p/, /t/, /k/, and /ŋk/ is 155, 170, 158, and 165 ms, respectively, whereas before

<sup>2</sup>We remind readers that the so-called long and short vowels of modern English differ less in length than they do in laxity, vowel height, and presence or absence of diphthongs. Because no single phonetic feature reliably distinguishes the two groups of vowels (e.g., the /ā/ is arguably both long and

the voiced /b/, /d/, /g/, and /ŋg/ the vowel lasts twice as long, at 300, 308, 357, and 288 ms, respectively. The voiced stop consonant extends its influence through the nasal to the preceding vowel. For example, the short vowel /ɛ/ located before the /d/ in *send* lasts 147 ms, but before the unvoiced /t/ in *sent* lasts only 123 ms. It should be noted that the voiced stop consonant does not assert this influence when it belongs to the following syllable. The vowel /ă/ in *ample* and *amble* were of the same duration, 148 and 147 ms, respectively, according to Chen's measurements.

Thus, the extent to which vowel duration varies in English is highly dependent on the immediate context in which the vowel is uttered. Vowel length variation contributes to the discrimination between voiced and voiceless consonants. The longer the closure time for voiceless consonants, the shorter the vowel length, and vice versa, perhaps to "assure a relatively even flow of syllables" (Chen 1970, p. 145). Vowels also differ in sound quality depending on consonantal context. For instance, vowel formants adapt to the formants of preceding and following consonants (Denes and Pinson 1963; Olive, Greenwood, and Coleman 1993).

If vowels vary in segment duration and sound quality depending on linguistic context, the establishment of a speech sound concept that entails such allophonic variation becomes very important. There is considerable evidence that the speaker/listener is biologically equipped to extract and use such speech sounds at an implicit level; indeed our speech processes are equipped with the flexibility and adaptability not only to abstract across the different realizations of a speech sound within a speaker but also to do so across speakers and dialects (Nygaard and Pisoni 1998). This feat is accomplished in the act of listening without conscious awareness of the phonemic units (Liberman, Cooper, Shankweiler, and Studdert-Kennedy 1967), and is referred to by such terms as "perceptual invariance" (Kent 1997) or "perceptual constancy" (Lively and Pisoni 1997). In contrast, the explicit awareness of these same

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unlike other short vowels), and because readers are more likely to be familiar with the orthographic terms long and short, we have elected to use the conventional diacritic markers used in dictionaries. Listed here are the vowel phonemes (presented in slashes) and a keyword for each: /ɪ/ as in *bit*; /ē/ as in *beat*; /ĕ/ as in *bet*; /ā/ as in *bait*; /ū/ as in *but*; /ū/ as in the first syllable of *beauty*; /ō/ as in *pot*; /ō/ as in *boat*; and /ă/ as in *tat*. The associated phonetic representations are presented in brackets in table I.

phonemes involves the cognitive ability to abstract, classify, and manipulate segments of spoken language (Liberman 1973, 1978). This ability is referred to as "phoneme identity" (Byrne and Fielding-Barnsley 1990; Murray 1998). The ability to partition an utterance into its component phonemes (Diehl 1986; Scott and Cutler 1984) depends on achievement of perceptual constancy and is referred to as phoneme segmentation in reading research (Høien et al. 1995; Lundberg, Frost, and Petersen 1988).

A letter can be considered a conceptual model that unites the different realizations of a speech sound under a single, visual label (Olson 1996). Indeed, there is some evidence that in skilled readers this conceptual model of speech (orthography) comes to dominate the phonetic perception of a word such that a literate person "hears" words through their representation in writing. They no longer notice, for instance, separate speech segments when the orthography ignores segmentation such as the /ks/ in *ox* (Moats 1994). In persons with a reading deficit, less coactivation between linguistic and orthographic representation is observed (Landerl, Frith, and Wimmer 1996), perhaps because they have never established secure phoneme identity. In order to use the orthographic component as a model for speech representation, perception of a speech sound may gradually change with growth in literacy, allowing for greater reading and spelling efficiency (Ehri and Saltmarsh 1995, but see Wimmer, Mayringer, and Landerl 1998). Establishing a consistent, abstracted identity for a vowel, irrespective of consonantal context, would facilitate the cognitive ability of linking a speech segment with the correct spelling of such a segment.

## HYPOTHESIS AND DESIGN

The present study tested the hypothesis that spelling errors involving vowels are linked to vowel perception deficits, following up on a prior study suggesting an association between vowel perception and reading skill. In that study (Post, Foorman, and Hiscock 1997), less skilled readers in second and third grade had more difficulties than highly skilled readers in perceiving two high vowels. The groups did not differ, however, in their production of words containing these same vowels, nor did they differ in their perception of the initial stop consonants /d/ and /t/.

Four experimental tasks were developed for the present study, both to clarify the vowel perception deficit observed in

the Post et al. study, and to link this deficit with vowel spelling. A vowel discrimination task (task 1) established whether comparing short and long high vowels, in two items presented in sequence, induced perception errors in less skilled readers. Vowel identification of four different short versus long vowel pairs (task 2) probed whether short/long vowel contrasts necessarily induce less skilled readers to make errors when each task item is presented singly in a forced choice format. A third task required identification of two short vowels to determine whether, apart from the short versus long contrast, other vowel contrasts present difficulties for less skilled readers. The three tasks give converging information about speech perception processes because the consonantal context surrounding the vowel in these three tasks was kept the same. In contrast with the Post et al. (1997) study, the tasks contain one- as well as two-syllable words. Finally, a spelling task that required insertion of a vowel letter into phonologically similar words (task 4) was administered to check for accuracy of spelling of the same vowels tested in the vowel identification tasks. Standardized measures of verbal memory and receptive vocabulary were used to describe the sample of students. Furthermore, the relation between vowel identification and performance on a standardized test of phonemic awareness was examined.

## METHODS

### EXPERIMENTAL MEASURES

*Task 1: Discrimination of the Vowels /i/ and /ē/.* Vowel discrimination was tested with pseudowords with a CVC or CVCV word structure. Stimuli for this task included 16 one- and 16 two-syllable words with /d/ or /t/ as initial consonant, and /b/ or /p/ as middle or end consonant (see the first column of table 1). The two-syllable words differed from the one-syllable words by adding the word ending "-y" (/ē/). Addition of the "-y" shifts the syllable boundary from a position directly after the final consonant to the position immediately after the vowel.\* A few slots in the CVC(V) word structure matrix were already occupied by existing dictionary words.

On each trial of the vowel discrimination task, the participants listened to two stimuli that differed only in vowel quality

\*Contrasting views about the syllable boundary are described in Akmajian, Demers, Farmer, and Harnish (1991), Treiman and Danis (1988), and Dollaghan and Biber (1993).

(the short high vowel /ɪ/ as in *dip* or the long high vowel /ē/ as in *deep*) and were asked to decide whether they were the same or different (an AX paradigm). Half of the 32 word pairs were identical and half were not. Participants listened first to the one-syllable word pairs, then, after a short break, to the two-syllable word pairs. An equal number of words in first position of the different condition contained a long vowel or a short vowel. Participants were asked to point to two identical blocks when they thought the words were the same and to two different blocks when they were different. The blocks in the different condition had contrasting colors (red and green instead of two green blocks) with pictures glued on top (rabbit and turtle instead of two rabbits). For half the participants, the different blocks were placed on the right and the identical blocks on the left. For the other half, the position of the blocks was reversed. Two word pairs were given as examples, one pair being different and the other the same. Then the children were asked to demonstrate their understanding of the task on three more trials with feedback. The vowel discrimination task had a coefficient- $\alpha$  reliability of .82.

**Task 2: Identification Tasks Involving Four Vowel Contrasts.** Vowel identification consisted of four separate tasks in which the following vowels were contrasted: /ɪ/–/ē/ as in *dip* — *deep*; /ē/–/ā/ as in *Deb* — *tape*; /ū/–/ū/ as in *tub* — *tube*; and /ō/–/ō/ as in *top* — *dope*. Each vowel identification task contained 16 items: half of the items contained a short vowel; the other half a long vowel. The word structures in which the short or long vowels were embedded were the same as in the discrimination task (see table I). The items were not presented in pairs as in task 1 but rather one at a time. Participants were asked to indicate whether they had heard the short vowel by pointing to one block, or the long vowel by pointing to two blocks. For half of the participants, the two blocks were placed on the right and the one block on the left; the position was reversed for the other half. At the beginning of each 16-item task, five demonstration trials were given. The coefficient- $\alpha$  reliability ranged from .80 for the /ɪ/–/ē/ task to .88 for the /ē/–/ā/ task, with reliability values of .82 for the /ū/–/ū/ task and .81 for the /ō/–/ō/ task. Across the four sets of contrasts (64 items), the reliability was .92.

**Task 3: Identification of the Vowels /ē/ Versus /ā/.** In this identification task, the participants were asked to make a forced choice between /ē/ and /ā/. Instead of blocks, male and female Barbie dolls (Ken and Pam) were used to indicate the vowels /ē/



Table I. List of items for vowel discrimination and identification.

SHORT VOWELS					
Stressed syllable	/ɪ/=[ɪ]	/ē/=[ɛ]	/ū/=[ʌ]	/ō/=[ɔ]	/ǎ/=[æ]
d__b (y)	dīb(y)	dēb(y)	dūb(y)	dōb(y)	dāb(y)
d__p (y)	dīp(y)	dēp(y)	dūp(y)	dōp(y)	dāp(y)
t__b (y)	tīb(y)	tēb(y)	tūb(y)	tōb(y)	tāb(y)
t__b (y)	tīp(y)	tēp(y)	tūp(y)	tōp(y)	tāp(y)
LONG VOWELS					
Stressed syllable	/ē/=[iy]	/a/=[ey]	/u/=[juw]	/ō/=[ow]	
d__b (y)	dēb(y)	dāb(y)	dūb(y)	dōb(y)	
d__p (y)	dēp(y)	dāp(y)	dūp(y)	dōp(y)	
t__b (y)	tēb(y)	tāb(y)	tūb(y)	tōb(y)	
t__b (y)	tēp(y)	tāp(y)	tūp(y)	tōp(y)	

Note: Dictionary notation is used to indicate the so-called short and long vowels; brackets indicate the phonetic realization of a phoneme. Despite the label, length does not reliably distinguish the two sets. For example, the phoneme /ǎ/ (or [æ]) can be as long in duration as the long vowels. For the set of items used, the long vowels were phonetically realized with a glide.

and /ǎ/. The participants were asked to point to Pam when they heard the vowel /ǎ/ as in *Pam* or *Pammy*, and to point to Ken when they heard the /ē/ as in *Ken* or *Kenny*. The words *Debby*, *dab*, and *tap* were used as three more feedback trials. Apart from the change in procedure, the administration of the test followed the same format as the short/long vowel identification tasks, including use of the same CVC(y) word structure. The 16 items are shown in the upper half of the second and fifth columns of table I. This task had a coefficient- $\alpha$  reliability of .86.

**Task 4: Vowel Spelling.** The words in the spelling test consisted of a family of Latin loan words ending in *-tion*. Each word in the spelling test lacked the vowel letter in the stressed syllable located immediately before the word ending *-tion* (see table II). The students were asked to fill in the missing letter after the word was dictated to them two times. Their choice of letter was not limited to two as was the case in the vowel identification tasks (forced choice tasks).

The words ending in *-tion* have highly consistent vowel spellings. The prefinal syllable of the test words comprised the short vowels /i/, /ē/, /ū/, or /ǎ/, consistently spelled with the

TABLE II. Vowel Spelling Test (Vowel letter insertion).

SHORT VOWELS	/ɪ/=[ɪ]	/ɛ/=[ɛ]	/ʊ/=[ʌ]	/ă/=[æ]
	fr <u>iction</u>	sec <u>tion</u>	s <u>uction</u>	cap <u>tion</u>
	ev <u>iction</u>	inv <u>ention</u>	eru <u>ption</u>	fac <u>tion</u>
LONG VOWELS	/ē/=[iy]	/ā/=[ey]	/ū/=[juw]	
	secr <u>etion</u>	el <u>ation</u>	evol <u>ution</u>	
	comple <u>tion</u>	ov <u>ation</u>	resol <u>ution</u>	

Note: Participants are required to insert the appropriate vowel (underlined here) in the syllable before *-tion*. This is an open-ended task.

Slashes denote the underlying phoneme; brackets denote the phonetic realization of the phoneme. In contrast to the short vowels, the long vowels are phonetically realized with a glide in English.

letters *i*, *e*, *u*, or *a*, respectively, followed by a consonant (*friction*, *section*, *suction*, *caption*), or the long vowels /ē/, /ā/, /ū/, consistently spelled with the letters *e*, *a*, *u* (*secretion*, *elation*, *evolution*). Because the number of words containing an /ō/ or /ō/ in prefinal position (*concoction*, *lotion*) is limited, they were not included.

The 14 items of the vowel spelling task had a coefficient- $\alpha$  reliability of .70. Separately, the reliability was .55 for the four words containing /ī/ and /ē/, .50 for the /ě/ and /ā/ words, .56 for the /ū/ and /ū/ words, and .36 for words with /ă/ and /ě/.

The experimental words for the first three tasks were pronounced on tape by a female speech-language pathologist speaking standard northeastern American English (see table I)<sup>3</sup>. The short vowels were pronounced on tape as monophthongs and the long vowels as diphthongs. Vowels in American dialects differ in degree of diphthongization (Olive et al. 1993; Treiman and Cassar 1997). The dictation words in task 4 (see table II) were pronounced by the intervention teacher when she administered the test in each classroom. She spoke the same northeastern dialect as the speech-language pathologist.

#### STANDARDIZED MEASURES

*Test of Phonological Awareness (TOPA)* (Torgesen and Bryant 1994). The TOPA was administered for comparison with the vowel identification task. The early elementary version

<sup>3</sup>Because this study was conducted in eastern Texas, the Northeastern dialect in which stimuli were presented differed from that of all of the children who were black, white, Hispanic, and Asian.

of the TOPA requires recognition of shared final consonants in illustrated one-syllable words. The TOPA has a coefficient- $\alpha$  of .89 for 8-year-old children.

*Digit Span subtest of the WISC-III (Wechsler 1991).* This digit span measure tests short-term verbal memory. The split-half correlation for 8-year-old children is .84.

*Peabody Picture Vocabulary Test, third edition (PPVT-III) (Dunn and Dunn 1997).* The PPVT-III tests receptive vocabulary and has a coefficient- $\alpha$  of .95 for 8-year-old children.

*Woodcock-Johnson Psycho-Educational Test Battery (WJ-R) (Woodcock and Johnson 1989).* The Basic Reading Cluster includes the Word Attack and Letter-Word Identification subtests of the WJ-R. Percentile scores for each participant use age as the basis for comparing norms. These percentile scores were then used to group participants in terms of reading skill. The Basic Reading Cluster reliability for 9 year olds is .96.

## PROCEDURE

The Woodcock-Johnson, the vowel discrimination and identification tasks, the TOPA, the PPVT-III, and the WISC-III Digit span were part of two testing sessions for an intervention study, and were interspersed between other tests. In the first session, the tests were administered in the following order: vowel discrimination, TOPA, digit span, and the Woodcock-Johnson. The order of testing in the second session two weeks later was vowel identification of the first three short/long contrasts, PPVT, and the final two vowel identification contrasts (/ɔ̃/-/ō/ and /ě/-/ǎ/). The tests were administered individually in two 45-minute sessions in a quiet room provided by the schools. The spelling test of vowel-letter insertion was administered in each classroom.

Vowel discrimination, identification of short versus long and short versus short vowels, and vowel spelling will be described as four separate tasks. Although the 14 items in the spelling test were not administered in vowel pairs, they were analyzed in short/long or short/short pairs to make the task comparable to the vowel identification task.

## PARTICIPANTS

A total of 164 second, third, and fourth graders attending two public schools in eastern Texas were given the Word Attack and Letter-Word Identification subtests of the WJ-R (Woodcock and Johnson 1989). Seven children were excluded from the study because they scored two or more standard deviations below the

mean on the Peabody Picture Vocabulary Test - III (Dunn and Dunn 1997) or on the Digit subtest of the WISC-III (Wechsler 1991). Two additional children were dropped because they were not available for both testing sessions. The remaining 155 participants were native speakers of English and had no history of speech or hearing deficits, or of emotional problems. In terms of SES, the participants were homogeneously lower middle class; all children lived in the same area. The sample consisted of black (77 percent), white (16 percent), Hispanic (6 percent), and Asian (1 percent) children. Overall, slightly more females (81) than males (74) were available for testing. In second grade, the ratio was equal (29 female, 29 male); in third grade, girls were outnumbered by boys (22 female, 30 male), and in fourth grade, girls predominated (30 female, 15 male).

The participants were divided into five groups based on their percentile score on WJ-R Basic Reading Cluster. Group 1 (the least skilled readers) scored at or below the 25th percentile, group 2 scored between the 25th and 51st percentile, group 3 between the 50th and the 76th percentile, group 4 between the 75th and 91st percentile, and group 5 above the 90th percentile. Although a cutoff at the 25th percentile designates poor readers in most studies (Siegel and Heaven 1986; Bowers 1995), a division into five groups was chosen because of preliminary data (Post 1997, manuscript) that suggested even intermediate readers lack fully accurate vowel perception. In correspondence with recent evidence that reading skill is distributed normally independent of intelligence (Foorman et al. 1996; Stanovich and Siegel 1994), the reading level of the children is described in terms of reading skill only, rather than in terms of discrepancy-based criteria.

The reading percentile range, reading group, gender, and grade of the remaining 155 children are described in table III. With the exception of Asian children (only 2), each race was represented in each reading group. The number of participants in each reader group ranged from 22 to 45.

Within each grade sampled, the very skilled readers (group 5) were the youngest and the least skilled (group 1) the oldest. Because these patterns are consistent across groups and age-adjusted scaled reading scores were used, age in months is collapsed over grade. As shown in table III, the less skilled the readers, the older they were; the more errors they made on the TOPA, and the lower their PPVT and WISC-III scores.

Multivariate analyses of variance (repeated measures) were chosen to analyze the data. A more appropriate analysis would

TABLE III. Descriptive Measures (mean and SD) for five groups of readers drawn from grade 2 through 4.

Group	n	Basic Cluster Percentile Range	Gender		Age in Months	PPVT SS	TOPA Errors	WISC-III Digits	WJ BASIC Cluster SS
			F	M					
1	(29)	(<26th percentile)	13	16	111.4 (10.8)	84.6 (10.9)	7.8 (4.7)	7.1 (2.2)	83.5 (5.5)
2	(45)	(26-50 percentile)	28	17	108.0 (9.8)	89.7 (11.1)	6.8 (4.1)	8.1 (2.2)	94.5 (3.3)
3	(35)	(51-75 percentile)	18	17	105.1 (11.0)	91.4 (13.5)	4.4 (3.3)	9.3 (2.6)	104.3 (2.8)
4	(24)	(76-90 percentile)	11	13	106.7 (10.9)	100.1 (10.3)	3.4 (3.0)	10.9 (3.3)	114.5 (2.6)
5	(22)	(>90th percentile)	11	11	99.0 (10.0)	104.9 (11.7)	1.4 (1.7)	11.8 (2.6)	132.2 (7.2)

Note. F=Female; M=Male; SS = Standard Scores; PPVT = Peabody Picture Vocabulary Test - III (Dunn and Dunn 1997); TOPA = Test of Phonological Awareness (Torgesen and Bryant 1994); BR = Basic Reading Cluster (Woodcock and Johnson 1989); Group 1 least skilled and group 5 very skilled readers; WISC = Wechsler Intelligence Scale for Children-third edition (Wechsler 1991).

be categorical data modeling but there were insufficient data for such an analysis with the number of conditions present. An alpha level of .05 was used for all statistical tests. With each statistical test, the probability of obtaining a particular value of the computed statistic was reported (Dixon 1998). In all analyses, reader (R) referring to five groups, was the between-group variable. When the omnibus test of main effects and interactions with the factor Reader was significant, the data were further analyzed with subsequent linear (L), quadratic (Q), cubic (C), and quartic (QR) polynomial contrasts. Multivariate analyses (Wilk's lambda) were reported because of violation of the assumption of sphericity.

## RESULTS AND DISCUSSION

### TASK 1: VOWEL DISCRIMINATION

In task 1, discrimination of the short and long high vowels /i/ as in *dip* and /ē/ as in *deep* was assessed in one- and two-syllable words. The question posed was whether less skilled readers could detect if vowel pairs were the same or different.

Few errors were made on the 32 pairs of items, but the least skilled readers made the most errors. Whereas group 1 made 2.6 errors on average, the other four groups made less than 1 error (.9, .8, .5, and .4 for groups 2 to 5). A two-way ANOVA was performed with reader group as the between-subjects variable and with repeated measures on same-different pairs. Neither the main effect of condition (same versus different) nor the interaction between condition and reader group were significant. The main effect of reader group was significant,  $F(4, 150) = 4.2$ ,  $p = .003$ , particularly the linear contrast indicating a linear trend with poorer readers making more errors,  $F(1, 150) = 11.3$ ,  $p = .001$ . Because the differences among reader groups were constant across same and different words, the responses were collapsed over this variable. When the variables of syllable, initial, and middle/final consonant and interactions with reader group were considered separately, no interactions with reader group were found.

The vowel errors declined linearly with increases in reading ability; however, even the least skilled readers (group 1) made few errors. Thus, the same-different task was easy, even for the least skilled readers. Apparently, less skilled readers can hear the contrast between the vowels /i/ and /ē/ when two pseu-

dowords containing these vowels are presented in direct sequence, even when the 32 items in the task are highly similar phonologically. Perhaps they only get confused when they have to consult the stored representation of a vowel, as in the vowel identification task involving the high vowels /ɪ/ and /ē/ (Post et al. 1997).

To explore this possibility, we tried to replicate the vowel identification task of Post et al. (1997), including the same 16 items used in task 1, but expanding our focus to other short/long vowel contrasts as well. We anticipated that less skilled readers would have difficulty with all short/long vowel contrasts presented singly in a forced choice format. We also hypothesized that vowel identification skills would be linearly related to reading skill (Foorman et al. 1996; Stanovich and Siegel 1994).

## TASK 2: VOWEL IDENTIFICATION OF SHORT AND LONG VOWELS

Apart from the /ɪ/ versus /ē/ contrast (*dip* versus *deep*), task 2 examines identification of three other contrasts: /ɛ/ versus /ā/ (*Debby* — *tape*), /ʌ/ versus /ū/ (*dub* — *tube*), and /ɔ/ versus /ō/ (*top* — *dope*). Before the results of the vowel identification tasks are examined, possible confounds on task performance were ruled out. These included age of the participants and lexical status of the stimuli. Links between perception and awareness will be explored by comparing vowel identification accuracy with performance on the elementary version of the TOPA (Torgesen and Bryant 1994).

*Vowel Identification Errors Over Grade.* Given evidence that the predictive power of phonemic awareness tests declines with reading age (Schatschneider, Francis, Foorman, and Fletcher in press), could vowel identification errors decline in higher grades or is it a stable characteristic? Although the mean (SD) of vowel errors in second grade was 15.2 (12.8), in third grade 16.7 (13.4), and in fourth grade 13.3 (10.2), an ANOVA of reader-group by grade indicated that neither grade nor the interaction between reader-group and grade was significant. Therefore, vowel identification seems to be a stable characteristic over these ages. Age differences will be ignored and the vowel identification data will be collapsed over grade.

*Lexical Status of Items in the Vowel Identification Tasks.* A second possible confound concerns lexical status of the items in the tasks. When phonological similarity between experimental words is used by exhausting the possibilities of a specific

word structure (CVC and CVC/y/), a few slots are usually occupied by existing dictionary words. Such words, shown in Table III, are *dub*, *dip(py)*, *Deb(by)*, *tip(py)*, *tub(by)*, *top*, *tape*, *taupe* (pronounced /töp/), *Toby*, *dope*, *dopey*, *tube*, *dupe*, *deep*, and *teepee*.

When the errors on words and comparable pseudowords were summed separately, and their sums were compared with repeated measures on words and pseudowords, their means were comparable:  $F(1, 150) = .003$ ,  $p = .96$ . In view of the significant interaction between the five groups of readers and the factor word/pseudoword ( $F[4, 150] = 2.9$ ,  $p = .02$ ), the least skilled readers (group 1) showed processing deficits with pseudowords. Because there was no difference of lexical status, subsequent analyses ignored the distinction between words and pseudowords in the vowel identification tasks.

*Vowel Identification of the Short and Long Vowel.* In the first analysis, the four vowel pairs (P) were compared in terms of their status as short or long vowels (V). In particular, the question was, "If the less skilled readers do worse on vowel identification in general, would the difference be the same for short and long vowels?" It was expected that the differences would be linear across groups. Several alternative approaches have been suggested for this type of problem (Allerup and Elbro 1998). We used the repeated measures approach because there was no constraint on the data to be better in one condition than the other; that is, we were not concerned with gains. Also, the better readers typically made few errors in either condition, which would have led to substantial missing data in methods which look at odds ratios or ratios relative to potential gain. In three subsequent analyses, the factors of Syllable (S: one or two-syllable), Initial Consonant (#C: /d/ or /t/), or Middle/Final Consonant (C#: /b/ or /p/) were added.

*Step 1: Vowel Identification Three-way ANOVA (Reader x Pair x Vowel).* Histograms for the four separate short/long vowel pairs are shown in figure 1. In a three-way ANOVA, the three main factors of reader ( $F[4, 150] = 16.2$ ,  $p = .001$ ), pair ( $F[1, 150] = 11.5$ ,  $p = .001$ ), and vowel ( $F[1, 150] = 25.4$ ,  $p = .001$ ) were significant. Interactions of reader with the other two factors were not significant except for the interaction of reader x vowel ( $F[4, 150] = 4.6$ ,  $p = .002$ ). The interaction of vowel and the linear contrast on reader was significant ( $F[1, 150] = 10.3$ ,  $p = .002$ ), as was the interaction of vowel and the quadratic contrast ( $F[1, 150] = 6.3$ ,  $p = .01$ ). This signifies that the differences between the short and long vowel were not constant across the groups of



readers. The curvature of the short and long graphs is dissimilar: the contrast is more linear for the short vowel than for the long vowel. In Figure 2, the linear decline of errors for the five groups of readers is shown for the short and long vowel errors collapsed over the four vowel pairs. More errors were made on the short vowel than on the long vowel by the two least skilled groups, with the errors for the short and long vowel converging for groups 3, 4, and 5.

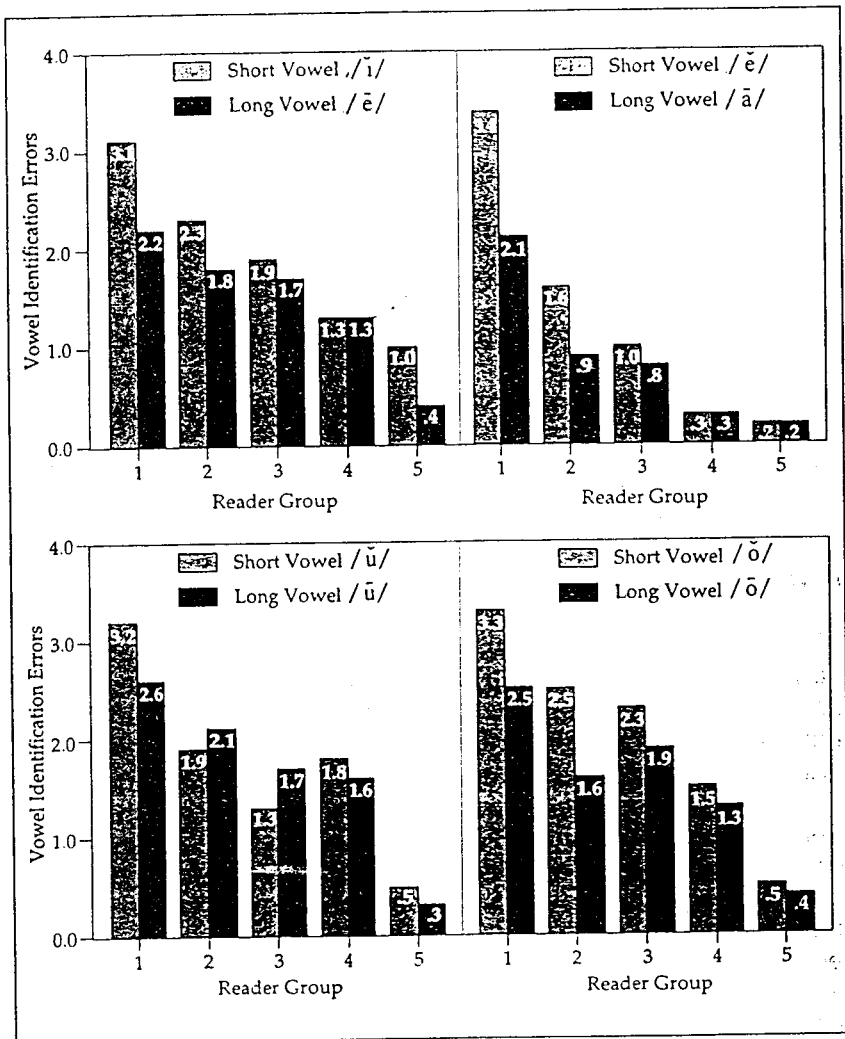


Figure 1. Histograms of identification errors for 4 pairs of short and long vowels.

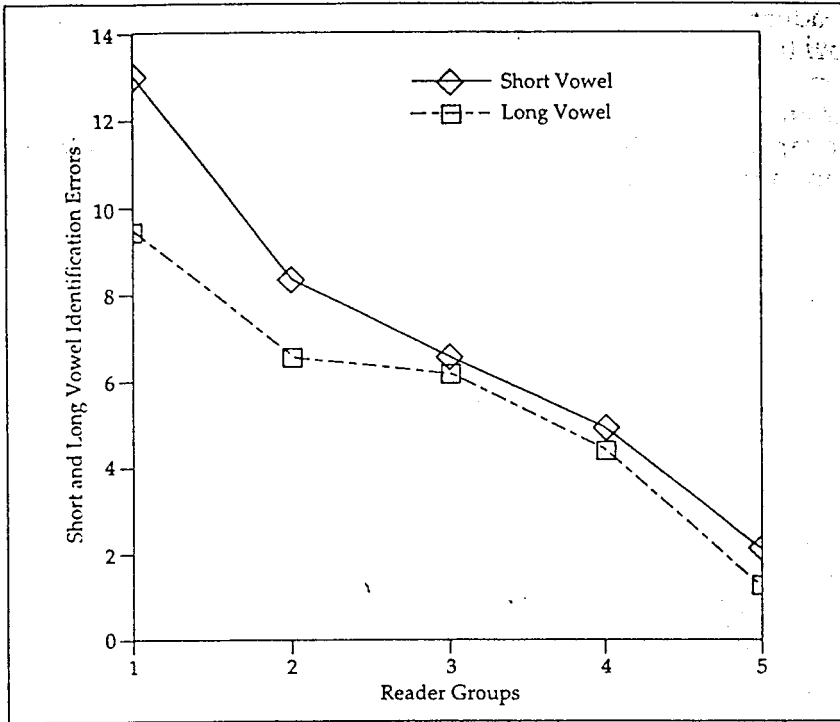


Figure 2. Vowel identification errors of short and long vowels collapsed over vowel pairs.

*Step 2: Addition of the Factors Syllable, Initial Consonant, or Middle/Final Consonant to the ANOVAs.* Separate addition of the factors syllable (S), initial consonant (#C), and middle/final consonant (C#) to the three-factor analysis of reader, pair, and vowel did not change the significance of the main effects for pair or vowel, or of the reader x vowel interaction. That is, across different syllable lengths, initial consonants, and middle/final consonant, and irrespective of vowel pair, the five groups of readers differed with respect to the identification of short versus long vowels. Vowel identification errors are linearly related to reading ability, with the low readers (group 1) making more than seven times as many vowel errors overall than the very skilled readers (group 5). Vowel identification seems, therefore, to be a strong indicator of reading difficulty. Furthermore, the lower reader groups tended to make more errors on the short than on the long vowels.

*Discussion.* Given the preponderance of errors in identifying short vowels in two-syllable words, we speculated that

some participants might have associated the number of blocks with the number of syllables instead of with short and long vowels. However, such a strategy should also lead to many errors in representing the long vowel in one-syllable words. Few such errors were made. Furthermore, the short vowel was difficult for the low readers (group 1) in all four vowel pairs, whereas groups 3 to 5 did not show this bias.

The answers in the first vowel identification task could also have been influenced by the presence of the unstressed word ending "-y" (pronounced /ē/ in two-syllable words). Perhaps the word ending facilitated the recognition of the long high vowel /ē/ in the first syllable of two-syllable words and limited the recognition of the short vowel /ī/ in two-syllable words. Although this was exactly the result we observed, the same pattern was also evident for the three other vowel pairs. Vowel pair and reader group did not interact, and histograms for three of the four pairs (except the pair /ē/-/ā/) are remarkably similar.

Another possibility is that vowel identification is difficult for less skilled readers because they cannot remember the association between vowel type and number of blocks. If so, perhaps this task (and not vowel discrimination) accurately reflects the difficulty less skilled readers have in associating a representation of a linguistic segment with an abstract symbol, the very task required in mastering phoneme-grapheme associations.

We next compared children's ability to discriminate vowels (assessed in task 1) with their ability to identify the same high vowels (required in task 2). As shown in Figure 3, only the vowel identification task gave rise to errors, such that there were large differences in variance across tasks. Nevertheless, an ANOVA was performed, which showed significant effects of reader group ( $F[4,150] = 8.6, p = .001$ ); type of task ( $F[1,150] = 117.5, p = .001$ ); and a significant interaction between reader group and type of task ( $F[4,150] = 3.2, p = .01$ ). The interaction of type of task and the linear contrast on reader was also significant ( $F[1, 150] = 12.5, p = .001$ ). This means that the differences between identification and discrimination errors were constant across the groups. Thus, type of task is important in establishing perceptual impairment for vowels in less skilled readers.

### TASK 3: VOWEL IDENTIFICATION OF /ē/ AND /ā/

After having established that the short/long contrast in identification is difficult for less skilled readers, we next considered the contrast between two short vowels in an identification task. Stark and Heinz (1996) observed that children with language

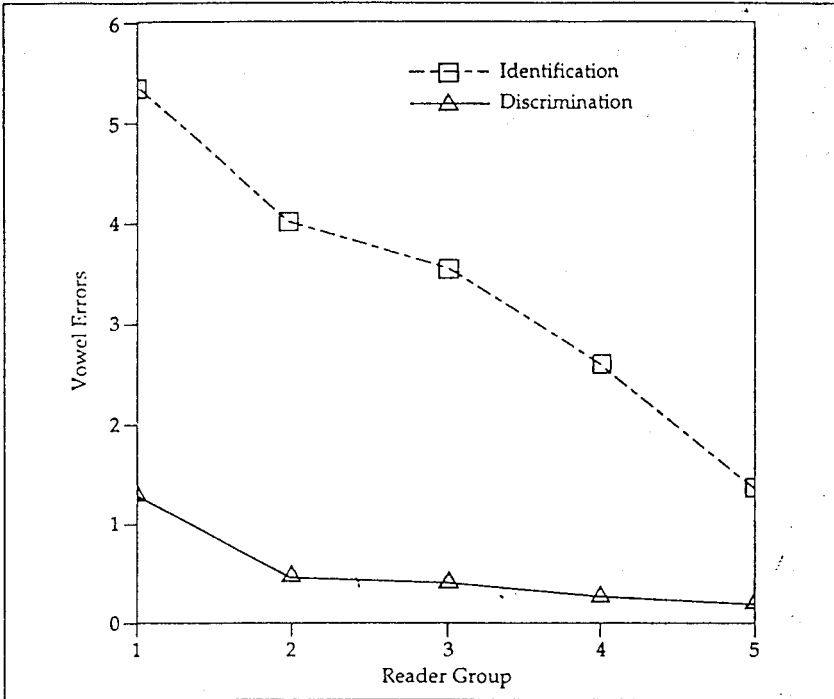


Figure 3. Vowel discrimination and identification errors for high front vowels /i/ and /ē/.

problems show deficits discriminating the /ē/ and /ǎ/. Although the /ǎ/ is longer in duration than the /ē/ in natural speech (Peterson and Lehiste 1980) and the two vowels also differ in sound quality, it was assumed that the contrast between the two short vowels would be hard to explain to children. Therefore, dolls instead of blocks were introduced as objects of sound association. In task 3, the two short vowels /ē/ and /ǎ/, as in *Debby* and *dab*, are contrasted. We expected that short vowels in the same consonantal context would be equally difficult to identify.

**Findings.** In a two-way ANOVA of reader group and vowel with repeated measures on the two short vowels, reader group ( $F[4, 150] = 9.4, p = .001$ ) and the interaction between reader and vowel ( $F[4, 150] = 2.9, p = .02$ ) were significant, but there was no main effect of vowel. Thus, the overall means on /ē/ and /ǎ/ were the same:  $M = 1.0, SD = 1.6$  versus  $M = 1.0, SD = 1.5$ . The linear contrast of the interaction of vowel  $\times$  reader was significant ( $F[1, 150] = 4.9, p = .03$ ). This signifies that the /ē/ was more difficult than the /ǎ/ for the less skilled readers (groups 1 and 2), whereas the more skilled readers (group 3 through 5) made more

errors on the /ă/. Errors for both types of vowels declined from group 1 to group 5 (see third and fourth column in table IV).

When the factors of syllable, initial consonant, and middle/final consonant were added separately, the interaction of reader x vowel remained significant, as did the linear contrast for this interaction. However, no other interactions with reader were significant except syllable x reader ( $F[1, 150] = 2.9, p = .02$ ). Fewer errors were made on the /ă/ in one-syllable items ( $M = .4, SD = .8$ ) than on the /ă/ in two-syllable items ( $M = .6, SD = .9$ ), whereas the errors in one- and two-syllable items remained the same for the /ě/ ( $M = .5, SD = 1.0$  and  $M = .5, SD = .9$ , respectively).

Less skilled readers made errors in the short vowel task, even with the changed procedure. Thus, vowel identification errors are not restricted to the short/long vowel contrast. As hypothesized, the number of overall errors made on the /ě/ and /ă/ was comparable.

*Discussion.* The presence of fewer errors on the /ě/ in the short/short vowel contrast (task 3) than in the short/long contrast (/ě/ versus /ā/ in task 2) can have four explanations. First, it may be that the forced choice between two short vowels is easier than between a short and a long vowel. Second, the results may be attributed to the change in task instructions. Dolls with well-known names (*Ken* and *Pam*) were used instead of blocks. The task with the dolls might have been more appealing to the children than the tasks with the blocks. Third, the names *Ken* and *Pam*, ending in the nasal /m/ or /n/, may have served to heighten the distinction between /ě/ and /ă/. Finally, the enhanced accuracy may stem from the fact that each target vowel was associated with a well-known name containing that vowel, instead of with an arbitrary symbol (the block).

Table IV. Vowel identification errors (mean and *SD*) for /ě/-/ā/ and /ě/-/ă/ comparisons.

Reader Group	/ě/= [e]	/ā/= [ey]	/ě/= [e]	/ă/= [æ]
1	3.4 (2.3)	2.1 (2.0)	2.3 (2.0)	2.1 (1.9)
2	1.6 (2.0)	0.9 (1.5)	1.2 (1.8)	0.8 (1.4)
3	1.0 (1.6)	0.8 (1.5)	0.4 (1.0)	0.8 (1.3)
4	0.3 (0.8)	0.2 (0.7)	0.4 (1.4)	0.8 (1.5)
5	0.1 (0.5)	0.2 (0.7)	0.1 (0.3)	0.3 (0.6)
<i>M</i> ( <i>SD</i> )	1.4 (2.0)	0.9 (1.6)	1.0 (1.6)	1.0 (1.5)

Some insights may be gained from looking at how well reading disabled adults ( $n = 36$ ) perceived these same short vowels when the same (paper and pencil) format was used across all five vowel identification tasks described thus far. These adult literacy students made an equal number of errors on the /ě/ as on the /ǎ/ in the short/short-vowel task (/ě/:  $M = 2.6$   $SD = 1.9$  and /ǎ/:  $M = 2.6$   $SD = 1.6$ ). This number was also equivalent to the number of errors in identifying /ě/ ( $M = 2.7$   $SD = 1.8$ ) when it was presented in comparison to the long vowel /ā/. In adults, number of errors on a specific vowel remained constant independent of the type of vowel contrast in the task. Further research is necessary to establish whether vowel identification errors are affected by the type of vowel contrast in the vowel pair.

In the demonstration examples, with the adults as well as with the children, the names *Pam* and *Ken* were used. Therefore, the use of dolls with well-known names instead of blocks must have simplified the task for the children. Instead of forcing an association between a vowel sound and a symbol (one or two blocks), a more direct comparison between the vowel sound in the first names *Ken* or *Pam* and the vowel in the presented experimental word could be made. In this respect, the /ě/-/ǎ/ identification task is more comparable to task 1 (vowel discrimination) in which two words presented in sequence were compared. The /ě/-/ǎ/ identification task with high frequency lexical exemplars is also similar to phoneme identity tasks used in research by Byrne and Fielding-Barnsley (1990, 1991) and Murray (1998) and in assessment tools such as the TOPA (Torgesen and Bryant 1994) or the *Batty, Betty, and Bitty* task (Ehri et al. 1987).

From tasks 1 through 3, we can conclude that the vowel identification test possesses unique characteristics. Our results indicate that less skilled readers do make vowel perception errors and that these errors can be induced through single presentation of phonologically similar words from which listeners must extract the appropriate vowel and pair it with an arbitrary symbol (block). Could vowel-spelling errors be induced when phonologically-related words are presented for spelling dictation?

#### TASK 4: VOWEL SPELLING

In task 4, vowel spelling in the *-tion* words is examined. The words are orthographically consistent and form a phonological neighborhood in that they are phonetically similar to one another (Luce and Pisoni 1998). The spelling of this group of

words had not been studied systematically in the participating schools and the words functioned, therefore, as pseudowords. Note that the classroom spelling test was administered to only 145 children because of the absence of 10 of the children at the time of administration of the spelling test. These 10 children were distributed evenly over the five groups and three grades.

*Short Versus Long Vowels.* The spelling errors for the short and long vowels declined linearly with the largest number of errors observed in the low skilled readers (group 1) and the least number by the very skilled (group 5). A three-way ANOVA was performed with five groups of readers (R) as the between-subjects variable and with repeated measures on the three vowel pairs (P) and on short versus long vowel (V). The main effect of reader group was significant ( $F[4,140] = 17.3, p = .001$ ) as was the linear contrast among the five groups of readers ( $F[1, 140] = 65.3, p = .001$ ). That is, errors declined with increasing reading skill. The main effect of vowel type was significant ( $F[1,140] = 7.5, p = .007$ ) but not the interaction between vowel type and reader group ( $F[4, 140] = .6, p = .63$ ). In other words, all reader groups made more errors on short rather than on the long vowels. The interaction between pair and vowel was significant ( $F[2,139] = 15.7, p = .001$ ) but not the interaction of pair  $\times$  vowel  $\times$  reader. In pairwise comparisons, the vowel pair / $\text{ĩ}/$ -/ $\text{ē}/$  as well as the pair / $\text{ě}/$ -/ $\text{ā}/$  differed significantly from / $\text{ũ}/$ -/ $\text{ū}/$ . This means that all readers made more spelling errors on the short vowels / $\text{ĩ}/$  and / $\text{ě}/$  than on the long vowels / $\text{ē}/$  and / $\text{ā}/$ , whereas they made the same number of errors on short / $\text{ũ}/$  versus long / $\text{ū}/$ . It should be noted that in the first two pairs, the spelling for short and long vowels changes from  $i$  to  $e$  and from  $e$  to  $a$ . In the third pair, the spelling is  $u$  for both members of the vowel pair (see figure 4).

*Two Short Vowels.* Whereas almost no errors were made on the / $\text{ā}/$  spelled with the letter  $a$ , many errors were made on the / $\text{ě}/$  spelled with the letter  $e$ . In an ANOVA with repeated measures on vowel, Reader group was significant ( $F[1, 150] = 10.4, p = .001$ ) as was the linear contrast ( $F[1,] = 34.7, p = .001$ ). The main effect of vowel ( $F[1, 140] = 101.5, p = .001$ ), the interaction of vowel  $\times$  reader ( $F[4, 140] = 5.4, p = .001$ ), and the vowel by linear contrast was also significant ( $F[1, 140] = 16.2, p = .001$ ). Thus, spelling errors on both short vowels declined over the five groups, but with a much steeper decline for the / $\text{ě}/$  than for the / $\text{ā}/$  (see figure 5).

*Discussion.* The short/long vowel contrasts showed the expected linear decline in spelling errors from low readers to

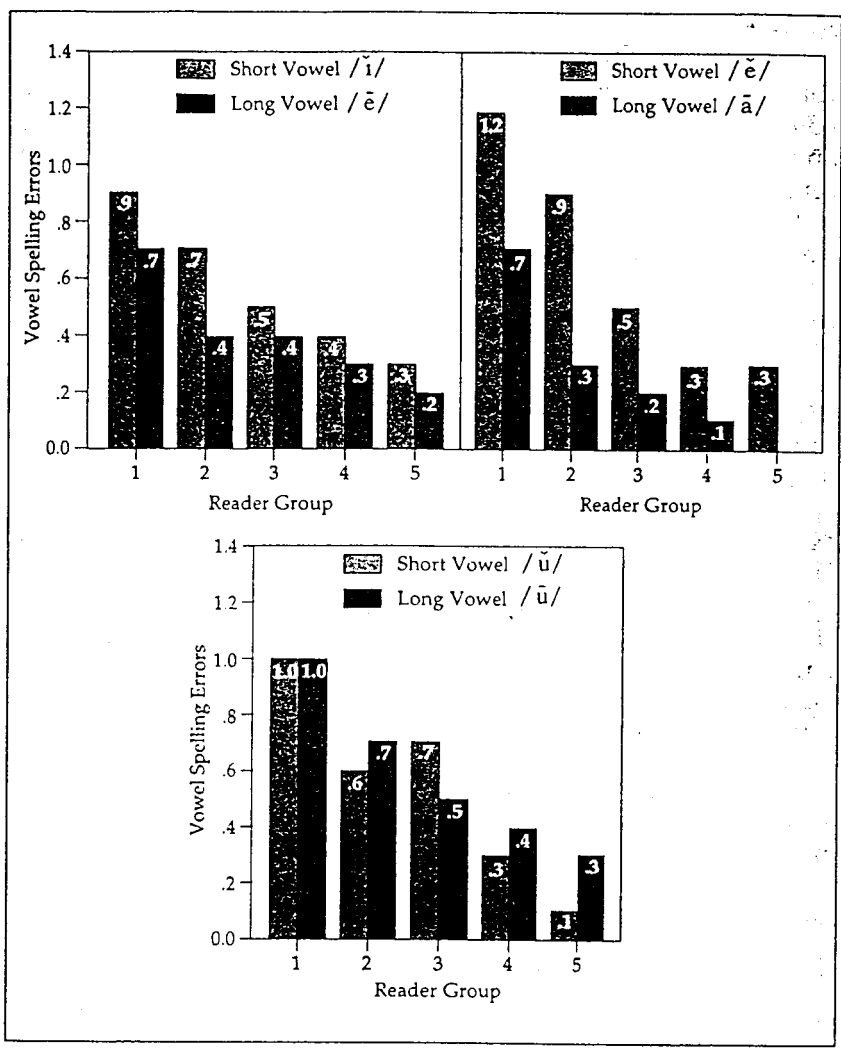


Figure 4. Histogram of short/long vowel spelling errors.

very skilled readers. Furthermore, more errors were made on the short /i/ and /ē/ than on the long /ē/ and /ā/. However, on the /ū/ and /ū/, the number of errors was comparable. Almost no errors were made on the short vowel /ā/, spelled as *a*. In Ehri et al. (1987) it was noticed that the short /ē/ and /i/ are often confused in spelling. Apparently, it is easier to spell the speech sound /ā/ with the letter *a*.



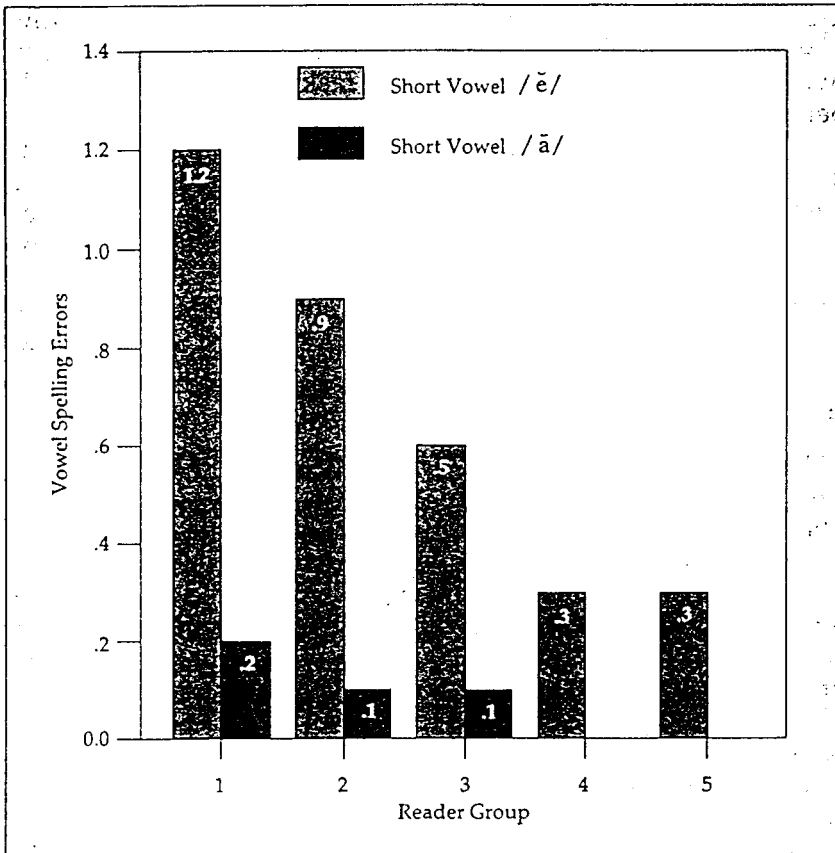


Figure 5. Histogram of short vowel comparison spelling errors.

### THE RELATION BETWEEN VOWEL IDENTIFICATION AND SPELLING

Categorization of spelling errors as errors against a specific phoneme instead of errors against an orthographic convention makes it possible to show the relation between vowel identification and vowel spelling. The correlation between vowel identification and vowel spelling for the short vowels (.52) was higher than that for the long vowels (.24). Separately, vowel spelling was significantly correlated with vowel identification ( $p = .01$ ) for all vowels except /ū/ ( $r = .15$ ,  $p = .07$ ) and /ū/ ( $r = .03$ ,  $p = .20$ ). The correlations were .34 for the /ī/, .31 for the /ē/, .41 for the /ā/, .35 for the /ā/, .19 for the /ā/, and .29 for the /ē/ in the short-vowel contrast. Because few vowel-identification ( $M = .99$ ,  $SD = 1.5$ ) or vowel-insertion errors ( $M = .39$ ,  $SD = 1.3$ ) were made on

the /ă/, the correlation between these two variables was low ( $r = .19$ ,  $p = .02$ ). It also should be noted that there were only two words per vowel in the spelling tasks in contrast to words per vowel in the identification task.

In sum, intercorrelations indicate that spelling accuracy is linked to vowel identification accuracy. In addition, more errors were made on the short vowels than on the long vowels for both vowel identification and spelling (except for spelling items to be spelled with *u*). If a phonological deficit exists at the level of the phoneme in less skilled readers, such a direct relation between vowel identification and vowel spelling would be expected. Quirks in the spelling of English (both /ŭ/ and /ū/ are spelled *u*) erode established regularities.

#### COMPARISON OF VOWEL IDENTIFICATION TO OTHER READING-RELATED MEASURES

The PPVT, WISC-III digits, and the TOPA also were administered to the children. The TOPA-Early Elementary requires recognition of shared final consonants in illustrated words. The ability to recognize (dis)similarity between different realizations of a phoneme across words might draw on acquisition of identity knowledge of phonemes (Byrne and Fielding-Barnsley 1990, 1991; Murray 1998). Therefore, it would be expected that vowel identification and final consonant comparisons as assessed by the TOPA are correlated. The correlation between Vowel Identification errors and TOPA consonant errors was .45 ( $p = .001$ ).

A multiple regression analysis was used to examine the contribution of vowel identification to the reading score controlling for the PPVT, digit memory, and the TOPA. When all four variables were entered into the model, they predicted 49.9 percent of the variance in reading scores ( $F[4, 150] = 37.4$ ;  $p < .01$ ). Examination of the regression parameters indicated that each variable predicted significant variance over and above the other variables in the model (all  $t$  with 150 df, all  $p < .01$ ): -4.0 for vowel identification; -2.8 for TOPA; 3.9 for digit memory; and 3.6 for the PPVT. To examine the degree of unique contribution of each predictor over and above the others, squared part correlations were computed. These indices represent the variance in the dependent variable predicted by the independent variable after partialing out the variance of the other independent variables from the predictor in question. These indices (.054 for vowel identification, .026 for TOPA, .050 for memory, and .042 for the PPVT) indicate that while there is considerable overlap in the predictors, the vowel discrimination task contributed at

least as much, if not more, unique variance to the prediction of reading as any other predictor.

## GENERAL DISCUSSION

In four tasks, discrimination, identification, and spelling of vowels were examined. Second, third, and fourth graders, divided into five groups according to reading skill, were tested with forced-choice vowel identification tasks of four short/long vowel contrasts (as in *Debby* and *tape*) and with a task contrasting the two short vowels /*ĕ*/ and /*ă*/ (as in *Deb* and *dab*). The short /*ĭ*/ (*dip*) versus long /*ē*/ (*deep*) contrast was also tested with a vowel discrimination task. Linguistic manipulation (Papagno and Vallar 1992) consisted of the exhaustion of a CVC and CVC(y) word formation. Some of the items belonged, therefore, necessarily to the category word. Because of the phonological similarity among the items, the coefficient- $\alpha$  reliability of the four short/long vowel identification tasks was high (.92). Vowel identification errors were linearly related with reading skill with the two least skilled reader groups making more errors on the short vowel than the long vowel, and the three more skilled reader groups making an equal number of errors on both type of vowels. Although fewer errors were made on the short vowel /*ĕ*/ in the short vowel contrast (/*ĕ*/-/*ă*/ as in *Debby* and *dab*) than in the short/long contrast (/*ĕ*/-/*ā*/ as in *Debby* and *tape*), this difference could be attributed to a change in task explanation. The results of the vowel discrimination and identification tasks point to a less stable core representation of the vowel in less skilled readers. Intercorrelations showed that spelling accuracy is linked to vowel identification accuracy.

If a phonological deficit exists at the level of the phoneme in less skilled readers, such a direct relation between vowel identification and vowel spelling would be expected. The results from this study show that vowels should not be neglected in the teaching of spelling or in preparatory speech awareness activities. Although errors in reading and spelling vowels was noticed in many studies (Bryson and Werker, 1989; Fowler, Liberman, and Shankweiler 1977; Fowler, Shankweiler, and Liberman 1979; Goswami, 1993; Landerl, Wimmer, and Frith 1997; Shankweiler and Liberman 1972; Steffler, Varnhagen, Treiman, and Friesen 1998), these errors have not been linked directly to less stable vowel representation in less skilled readers.

### COMPARISON OF THE RESULTS WITH OTHER VOWEL STUDIES

In a replication of the reading study by Fowler, Shankweiler, and Liberman (1979), Bryson and Werker (1989) noted that both skilled and less-skilled readers had no difficulty in detecting same versus different vowel pairs in a vowel discrimination task. Reed (1989) also found no vowel deficits when two short vowels were presented in sequence in her vowel discrimination task. In that study, children were trained to respond to the two short vowels /*ě*/ and /*ǎ*/ which were presented in sequence with an interstimulus interval (ISI) of 400 ms. Each vowel had a duration of 250 ms. Participants were first trained to associate a response key with each one of the two vowels, and were then asked to indicate the temporal order in which the two vowels were presented by pressing the two keys in the same order. There were four possible sequences of stimuli.

The reason that both reading disabled and typically reading children performed well on the vowel discrimination tasks used by Bryson and Werker (1989) or in the study by Reed (1989) could pertain to the successive presentation of two vowels. This type of presentation was comparable to the same/different presentation in task 1 (vowel discrimination of the short and long high vowel /*ĩ*/-/*ē*/) in the research presented here, a task on which the less skilled readers also made few errors. Therefore, it appears that task presentation of two stimuli in sequence is not demanding enough to trigger vowel errors in less skilled readers without further manipulation.

### PHONEMIC AWARENESS TASKS VERSUS PHONEMIC IDENTITY

Phonemic awareness tasks such as rhyming, blending, and segmentation predict reading quite accurately. However, most tasks provide a global test of the presence or absence of phonemic awareness (Torgesen and Bryant 1994; Yopp 1995), but specific speech sound sensitivity is not tested. If a reading deficit is due to the failure to establish phonological immediacy in reading or spelling, a deficit at the level of the specific phoneme should also be expected. If a phonological representation is required for the purpose of holding a word in working memory (Baddeley, Eldridge, and Lewis 1981; Kleiman 1975) and this representation is incomplete or underspecified (Frost 1998) regarding vowel length, efficient use cannot be made of orthographic cues such as the silent letter *e* to indicate a preceding vowel (for example, *lame*). Therefore, phonemic awareness

could better be defined as a set of specific linguistic subskills the presence of which stimulates the immediate presence of phonological representation in reading and spelling, rather than as a global unified concept. The ability to recognize quickly and consistently the different realizations (allophones) of a single phoneme in spoken word context (Byrne 1998; Murray 1998) is one important component in the development of literacy. The tasks that probe for this type of awareness are easier to administer and less frustrating for less skilled readers to complete than are phonemic awareness tasks that focus on segmentation and deletion. Phoneme identity tasks could also be used to develop alphabetic insight when directly linked with letter identification (Byrne and Fielding-Barnsley 1990).

For less skilled readers, phoneme identity might never be secure enough to establish phonological immediacy in reading and spelling. It is possible, therefore, that they will not establish the knowledge of orthographic patterns that may alter their phonological representation for greater reading efficiency (Moskowitz 1973; Ehri and Wilce 1980). Earlier reading studies established that less skilled readers are insensitive to contextual regularities in English orthography (Bryson and Werker 1989; Fowler et al. 1979). The vowel identification test highlights insensitivity toward contextual regularities in English phonology as exhibited in allophony.

#### TEACHING STRATEGY AND THE FORCED CHOICE TASK

Because successful readers link spelling patterns to invariant phonetic categories extracted from the speech signal, instruction could direct the learner's attention to perceptual constancy through the use of minimal word pairs (Byrne 1998; Lively and Pisoni 1997). In this way, the attention of beginning readers could be directed to the systematic impact of surrounding segments on the phonetic quality of the vowel and of the vowel on the adjacent consonants. Reading and spelling methods that introduce new letters in strict sequence always practice their newly introduced letters in neighborhoods of phonologically similar words that are orthographically transparent (Cox 1984). The forced-choice task could simplify the introduction to a new group of similar words even more. Instead of asking a reading disabled student to read a whole row of similarly spelled words, one could start by showing the student one word and asking whether that word (*man*) is the word *man* or *men*. A yes/no question could force the student to acknowledge that the contrasting vowels are also spelled differently. A subsequent contrast between *man* and

*mam* could show that the two vowels belong to one phoneme and are spelled with the same letter, although their articulation is slightly different. In beginning literacy instruction, systematic vowel nuances within the phoneme are usually glossed over. Now that we begin to understand the phonological intricacies of our speech and the difficult transition from speech to literacy code, perception research suggests that apart from phonemic awareness activities, reading and spelling instruction should include very systematic development of speech sound identity in direct relation to spelling. Reading is the effective adaptation of basic language skills (Cox 1988).

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