SCIENTIFIC STUDIES OF READING, 3(4), 363–379

Phonological and Orthographic Influences on Children's Vowel Spelling

Connie K. Varnhagen, Patricia M. Boechler, and Dorothy J. Steffler

University of Alberta

Vowel representations are particularly difficult for children to learn because most vowel phonemes can be spelled in several different ways. Children in Grades 1, 2, and 3 spelled nonwords with an ambiguous vowel and reported their spelling strategies. Analysis of the children's spellings and strategy reports revealed a shift in relying solely on phonological information to considering orthographic information for making vowel letter choices. Implications for vowel spelling development are discussed.

Why do we spell *walk* with an *a* but *sock* with an *o*? The complexities of English orthography are not easily mastered, making spelling a difficult skill for children to acquire. The goal of this study was to investigate the differential influences of two types of linguistic information that children rely on during spelling—phonological information (sound–letter correspondences), and orthographic information (knowledge of conventional spellings and spelling rules).

Phonological information is used to map sounds to letter representations. This involves several component skills: (a) the ability to recognize distinct and separate sounds in words, (b) the ability to assign a letter or combination of letters to represent that sound, and (c) the ability to manipulate individual sounds. Because spelling requires the representation of sounds with appropriate letters, phonological information is essential for spelling. However, because English has inconsistent sound–letter correspondences, phonological information is not sufficient to master spelling. Cumulative knowledge of the written form of English words, or orthography, is also necessary for competence in spelling.

Requests for reprints should be sent to Connie K. Varnhagen, Department of Psychology, University of Alberta, Edmonton, Alberta, Canada, T6G 2E9. E-mail: varn@ualberta.ca

Orthographic information includes information about the typical and legal letter strings that we encounter in English. For example, a typical letter sequence would be the *ake* in *cake*. It is a frequently occurring letter pattern (e.g., *cake*, *bake*, *make*), the pronunciation and spelling of which would become familiar even to a beginner reader or speller in a relatively short time. An atypical, but still legal, letter string would be *ache*. An illegal letter pattern would be one that never occurs in English, such as *caeyke*.

A number of researchers documented an age-related progression from reliance on phonological to orthographic information when learning to spell (e.g., Ehri, 1986; Frith, 1985; Henderson & Beers, 1980; Stage & Wagner, 1992; Templeton & Bear, 1992). Frith argued that children begin to use orthographic information when they have a sufficient understanding of phoneme–grapheme correspondence. However, Goswami (1988) argued that children are able to make use of orthographic information to make spelling decisions even as very young spellers. In her study, 7-year-old children were taught analogous pairs of words before testing. The results showed that children made more appropriate analogies to words that were both a phonological and orthographic match (e.g., *beak*, *speak*) and less inappropriate analogies to words that were phonological matches only (e.g., *meek*, *speak*). This suggests that the children's spellings were influenced by orthographic information even at young ages. Ehri, Wilce, and Taylor (1987) also found that Grade 2 children's identification of vowel sounds improved when children studied the spellings of the words as opposed to just listening to their pronunciation. These studies suggest that orthographic information, as well as phonological information, plays a part in vowel identification and representation.

Research on vowel spelling is important because vowels are particularly difficult to spell. Vowel errors represent a substantial proportion of children's spelling errors (Read, 1975; Treiman, 1993). Treiman (1993) found that vowel substitutions accounted for a relatively high proportion of children's vowel spellings. Children commonly substituted a vowel that had similar phonetic properties to the correct vowel (e.g., *furmur* for *farmer*). Ehri et al. (1987) found that when children were asked to categorize vowel sounds in spoken words, the errors they made reflected choices of vowels that were adjacent on a phonological continuum—that is, a vowel was chosen that sounded similar to the spoken vowel.

Phonological difficulties arise because, in English, the same vowel sound is often represented in a number of different ways; for example, the phoneme, /ɑ/, can be represented in various ways, as in *slop* or *swamp*. This unpredictable mapping of letters to vowel sounds is problematic. Although the vowel is generally linked with the rime in English (Kessler & Treiman, 1997; Treiman, Mullennix, Bijeljac-Babic, & Richmond-Welty, 1995), sometimes the orthographic representation of the vowel phoneme is dependent on the onset. For example, the vowel in *swan* appears to be controlled by the onset because the only four-phoneme words in which the vowel is pronounced /ɑ/ are words beginning with *sw* (e.g., *swan*,

swat, swath, compared with *clan, scan, span*). Therefore, knowledge of an orthographic convention is often necessary for correct representation of vowel sounds. Thus, both phonological and orthographic information are important for vowel representation in spelling.

The goal of this research was to investigate the role of phonological and orthographic information in vowel selection. This research is important because it can shed light on how children learn to represent the many ambiguous phonemes that make up the English language. Children completed a nonword spelling test to prevent direct retrieval and allow us to control the adjacent letters that might influence vowel representation. The target items were nonwords that contained a single ambiguous vowel sound, /ɑ/. This vowel sound is typically represented with the letter *o* but it is also legally represented by the letter *a* (Hanna, Hanna, Hodges, & Rudorf, 1966). Half of the nonwords contained letter strings where the conventional vowel spelling matched the conventional representation of the single vowel sound, /ɑ/ (e.g., /slɑk/ as in *slop, slot*); we labeled these letter strings *o-convention nonwords.* The other nonwords contained letter strings where the conventional spelling contained an atypical, but still legal, representation of the vowel sound (e.g., /swɑk/ as in *swan, swat*); we labeled these letter strings *a-convention nonwords.*

We compared children's vowel choices (*o* vs. *a*) in their spelling of o-convention and a-convention nonwords to examine how children use phonological and orthographic information. If children rely on phonological information alone, we would expect their vowel choices to illustrate the most typical representation for the sound of an individual vowel (e.g., *swok*) because /ɑ/ is most commonly represented by *o*. If children rely on orthographic information in addition to phonological information, we would expect their knowledge of conventional spellings of particular letter combinations to influence their choices (e.g., *swak* by analogy to *swan, swap*, and *swat*).

Previous research indicates that children are able to use orthographic information in their spelling, even at young ages, but the use of this information is affected by the presence or absence of analogous clue words during testing (Goswami, 1988). We investigated if children make use of analogies to orthographic information spontaneously, without the presentation of analogous words prior to or during testing. Strategy reports were collected as supporting evidence for the inference that certain spellings were derived from phonological information alone, whereas others were constructed from a combination of phonological and orthographic cues.

To validate the children's self-reported spelling strategies, we also collected and examined typing latencies. Johnson and Siegler (1999) found that children took longer to spell words when they reported using backup strategies than when they reported having retrieved the spelling from memory. Similarly, Steffler, Varnhagen, Friesen, and Treiman (1998) found retrieval to be faster than

rule-based or phonetic strategies. They also found that letter-by-letter typing latencies were consistent with different types of strategy reports. Finally, Steffler, Varnhagen, and Boechler (1998) found that children's and adult's letter-by-letter typing latencies were consistent with their different phonetic strategy reports. Based on these research findings, we hypothesized that veridical (accurate and faithful) strategy reports would lead to different typing latencies. We predicted that it would take less time to type the vowel for nonwords spelled by analogy than for nonwords that were sounded out. This prediction is based on the inference that analogy to known words allows direct retrieval of the vowel but sounding the word out requires the application of phoneme-to-grapheme translation, a more time-consuming process than direct retrieval (Steffler, Varnhagen, Friesen, & Treiman, 1998).

Finally, we investigated the differential effects of phonology and orthography across grades. In accordance with previous research on the use of phonological and orthographic information in spelling (e.g., Ehri, 1986; Frith, 1985; Henderson & Beers, 1980; Stage & Wagner, 1992; Templeton & Bear, 1992), we expected a trend toward an increase in orthographically based vowel choices. To address this developmental aspect, we tested children from Grades 1, 2, and 3.

METHOD

Participants

We tested Grade 1, 2, and 3 children from four middle-class elementary schools. There were 45 Grade 1 children (age: $M = 6$ years 6 months, $SD = 4.1$ months), 57 Grade 2 children ($M = 7$ years 6 months, $SD = 3.5$ months), and 52 Grade 3 children ($M = 8$ years 6 months, $SD = 3.6$ months). Grade 3 children were tested in the fall, Grade 2 children in the winter, and Grade 1 children were tested in early spring of the school year.

All children participated on a voluntary basis; parental consent was obtained, and children were told they were allowed to quit at any time during the session. Children of all spelling abilities were tested except those identified by their teachers as having significant learning difficulties and those who did not speak English as their first language.

Materials

The nonword spelling test was designed to reflect the type of information (phonological or orthographic) that children are using to aid in vowel choices. The test consisted of 25 four-letter, one-syllable nonwords, with 16 target items and nine foils to prevent decisions based on similar nonwords.

Each of the 16 target nonwords contained a single ambiguous vowel sound pronounced /ɑ/. The /ɑ/ sound was specifically chosen because it can be spelled in a number of different ways and does not sound like a letter name. The target nonwords, 8 a-convention and 8 o-convention, were categorized by orthographic convention. The o-convention nonwords contained consonant pairs that would typically be accompanied by an *o* to represent this sound in English orthography (e.g., /slɑk/ as in *slop*, /nɑst/ as in *cost*). The a-convention nonwords contained consonant pairs that would typically require the /ɑ/ sound to be spelled with an *a* in English orthography (e.g., /swɑk/ as in *swamp*, /nɑlt/ as in *salt*). According to Hanna et al. (1966), 93% of spellings with a medial /ɑ/ were spelled with an *o* and 6% were spelled with an *a*.

The onset controlled the vowel convention for 4 nonwords in each condition and the coda controlled the vowel convention for the other 4 nonwords in each condition. The onset, *sw*, and the coda, *lt*, were used to create a-convention nonwords: Using a computer program that searches for words based on letter matches (Treiman, Mullenix, Bijeljac-Babic, & Richmond-Welty, 1995), we found six four-phoneme root (unaffixed) words beginning with /swɑ/ that were spelled *swa* and no words beginning with /swɑ/ that were spelled *swo*. Similarly, we found five four-phoneme root words ending in /ɑlt/ that were spelled *alt* and none spelled *olt*. The onset, *sl*, and coda, *st*, were used to create o-convention nonwords. Our search yielded six four-phoneme root words beginning with /slɑ/ that were spelled *slo* and two words spelled *sla*; these *sla* words, *slav* and *slaus*, are so low frequency that they are not included in Carroll, Davies, and Richman (1971). We found two four-phoneme words ending with /ɑst/ and spelled *ost* and no words spelled *ast*. We used frequencies for four-phoneme real-word onset and coda phonological neighbors to the nonwords from the Carroll et al. Grade 3 norms to select surrounding consonants. The 16 nonword stimuli, their real-word onset and coda phonological neighbors, and word frequencies are found in the Appendix.

The nine additional four-phoneme foils (e.g., *flim, greb, gisp, runk*) were constructed to contain a nonambiguous vowel.

Procedure

This research was part of a larger project that included measures of reading and spelling ability, print exposure, knowledge of orthography, and phonological skills (Boechler, Varnhagen, & Steffler, 1999). The larger project consisted of two test sessions: The first session was 20 min in duration and the second was 35 min in duration. The nonword spelling test for this study occurred in the second test session.

Prior to the session, the researcher informed the child of the nature of the task and asked if he or she was ready to proceed. The researcher told the child that he or

she would be spelling words on a computer and that these words were all "pretend" words, not real words. The child was asked to spell the pretend words whatever way seemed the best.

The researcher sat beside the child during the computer spelling test. No specific feedback was given regarding the child's performance. The researcher was available to answer any questions about the procedure and was able to control the computer presentation with a start–stop key. The child was asked to type only with the index finger of the hand he or she wrote with. The child was also instructed to use the backspace key to make letter changes. When the child was ready, the researcher pressed the Enter key to start the trial.

Nonwords were presented via the digitized speech function of a Macintosh computer. The nonword was presented once, then repeated in a context sentence as a noun, then repeated once again (e.g., "/swɑk/. Grandpa put the /swɑk/ in the mailbox. /swɑk/."). A tone and blinking cursor indicated to the child when to begin typing. The letters appeared in a response box on the screen as the child typed. Once the child completed typing to his or her satisfaction, the child pressed the Return key. The computer recorded the child's spellings, including backspacing, and letter-by-letter typing latencies. Children were presented with two additional practice nonwords at the beginning of the session to familiarize them with the procedure. Nonwords were presented randomly to each participant.

After each nonword was spelled, the researcher asked the child, "How did you decide how to spell that word?" This question was sufficient to elicit a response from the child, and further probes were not necessary for the majority of the children. The researcher recorded the child's response, then proceeded to the next trial.

Scoring

Spellings. All recorded spellings were categorized as plausible or implausible. Plausible spellings were those that contained letters that legally represented each phoneme in the nonword (e.g., plausible representations for /swɑk/ were the following: *swoc, swok, swock, swac, swak, swack, swalk, swauk, swawk*). Nonwords with recorded backspaces were included in this category if the final spelling was plausible. Implausible spellings were those that contained too few or too many letters to represent the phonemes as well as phonologically incorrect spellings (e.g., implausible spellings for /swɑk/ were the following: *swk, swo, s, skwok, thock*). Spellings such as *swoke* for /swɑk/ were also categorized as implausible because we could not ascertain whether the letter, *e*, represented a phonetic representation of /k/ as *ke* or an orthographic convention relating to the representation of the medial vowel as long. The plausible category was subdivided into *o* spellings and *a* spellings. Only plausible spellings were analyzed.

Strategies. Strategies were categorized into three types: phonetic, analogy, and other. Reports were coded as phonetic if they referred to the sound of the nonword or its individual letters (e.g., "I sounded it out," "I said the letters in my head," "It said nnn-aaa-lll-tttt"). Reports were coded as analogy if the child made reference to a real word (e.g., "/nɑlt/, it sounds like 'salt,'" "It has the word 'all' in it"). Strategies were coded as other if they included direct retrieval statements (e.g., "I remembered it," "I just knew it") and a variety of idiosyncratic responses (e.g., "My auntie told me," "I had one of those," "I guessed"). Only the phonetic and analogy categories were analyzed.

RESULTS

Ten Grade 1 children did not produce any plausible spellings and therefore could not be included in the analyses. Because this resulted in a 40% difference in sample sizes, a random sample of 35 children each from Grades 2 and 3 were chosen and combined with the 35 children from Grade 1 for the following analyses. Results from this subset mirrored the results of analyses conducted with the full sample of children, however.

The number of plausible spellings increased over grades, with means of 10.2, 11.9, and 13.1 (SE = 0.75, 0.62, and 0.48) for Grades 1 to 3, respectively. This increase across grade was supported by a statistically significant one-way analysis of variance (ANOVA) for number of plausible spellings, $F(2, 102) = 5.22$, $p < .01$. According to Tukey's honestly significant difference (HSD) post hoc analyses, Grade 3 children produce more plausible spellings than Grade 1 children, HSD = 2.1, $p < .01$.

Spelling

Because *o* is the common spelling for the /ɑ/ sound, we expected that young children who frequently use phonological information in their spelling would spell the nonwords with *o*s. This was indeed the case; *o* spellings were consistently frequent across grades, M = 9.1, 9.5, and 9.6 (SE = 0.83, 0.74, and 0.65), for Grades 1 to 3, respectively. On the other hand, *a* spellings increased from Grade 1 to 3, M = 1.1, 2.4, and 3.5 (SE = 0.39, 0.48, and 0.60), for Grades 1 to 3, respectively. Results of a one-way ANOVA for *a* spellings supported this difference across grades, $F(2, 102) = 5.90$, $p < .005$. According to Tukey's HSD post hoc comparisons, *a* spellings increased significantly from Grade 1 to Grade 3, HSD = 2.12, $p < .05$.

This increase in *a* spellings might reflect children beginning to use orthographic information around Grade 2. To examine whether orthographic information about conventional spellings influenced vowel choice, we conducted a 1 between-subject (grade) × 2 within-subjects (orthographic convention and spelling)

repeated measures ANOVA on children's spelling. As shown in Figure 1, there was a significant three-way interaction, $F(2, 102) = 13.12, p < .01$. According to Tukey's HSD post hoc comparisons, children more frequently produced *o* spellings than *a* spellings of o-convention nonwords at each grade, HSD = 2.07, $p < .05$. By contrast, Grade 1 children produced more *o* spellings than *a* spellings for a-convention nonwords, Grade 2 children produced marginally significantly more *o* spellings than *a* spellings, and Grade 3 children produced equal numbers of *o* and *a* spellings. Comparing their vowel choices across grades as a function of percentage of plausible spellings for a-convention nonwords, we found that 14% of the plausible a-convention nonwords spelled by Grade 1 children were *a* spellings, compared with 34% and 46% for Grades 2 and 3 children, respectively.

The interaction between grade and spelling for the a-convention nonwords may indicate a shift across grades from relying solely on phonological information to beginning to use orthographic information in spelling a-convention nonwords. The analyses we conducted with strategy reports, described next, support this conclusion.

Strategy Reports

Initially, children's strategy reports were examined to determine general patterns using a 1 between-subject factor (grade) × 1 within-subjects factor (strategy report) repeated measures ANOVA on percentage use of phonetic, analogy, and other strategies. There was a significant main effect of strategy, $F(2, 204) = 58.51, p <$

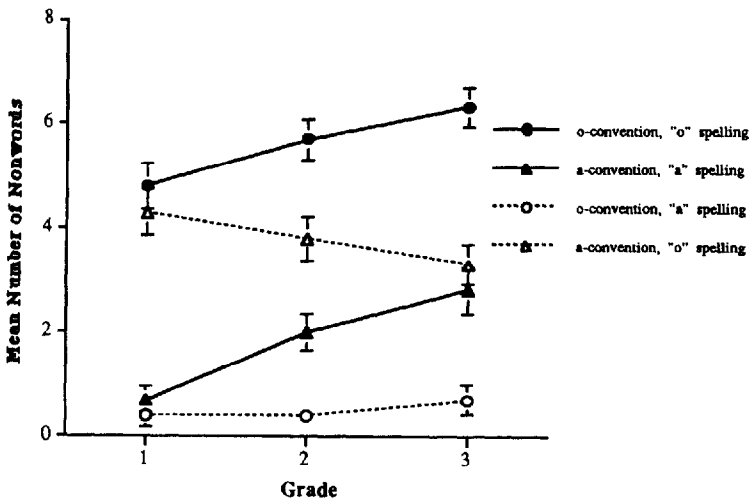

FIGURE 1 Mean number of plausible spellings (with *SE*) by grade, vowel choice, and orthographic convention.

.001; as expected, phonetic strategies ($M = 65\%$, $SE = 4\%$) were reported more often than analogy ($M = 20\%$, $SE = 3\%$) or other strategies ($M = 15\%$, $SE = 3\%$), HSD = 12%, $p < .05$.

This main effect was tempered by an interaction between grade and strategy report, $F(4, 204) = 5.50$, $p < .001$. As shown in Figure 2, percentage of reports of phonetic strategies decreased slightly as analogy reports increased across grade. Tukey's HSD post hoc analyses revealed a marginal decrease in phonetic strategy reports from Grade 1 to Grade 3 and a statistically significant increase in analogy strategy reports from Grade 1 to 2, HSD = 22%, $p < .05$. As well, although Grade 1 and 2 children reported phonetic strategies more frequently than analogy, Grade 3 children reported analogy as frequently as phonetic strategies, HSD = 28%, $p < .05$. This general increase in the use of analogy strategies over grade is consistent with previous research documenting the development of the use of analogy strategies (e.g., Deavers & Brown, 1997; Johnson & Siegler, 1999; Nation, 1997).

Our analysis of typing latencies provided support for the veridicality of the children's strategy reports. Based on previous research (e.g., Johnson & Siegler, 1999; Steffler, Varnhagen, et al., 1998), we hypothesized that longer latencies to type the vowel would occur when children reported using a phonetic strategy than when they reported using analogy to a known word. Averaged across participants and stimuli, the average latency to type the vowel was 1,922 msec ($SE = 67$ msec) for phonetic strategy reports and 1,666 msec ($SE = 84$ msec) for analogy strategy reports. We did not analyze the latencies further for three interrelated reasons: (a) Many children did not report using both strategies, limiting the number of laten-

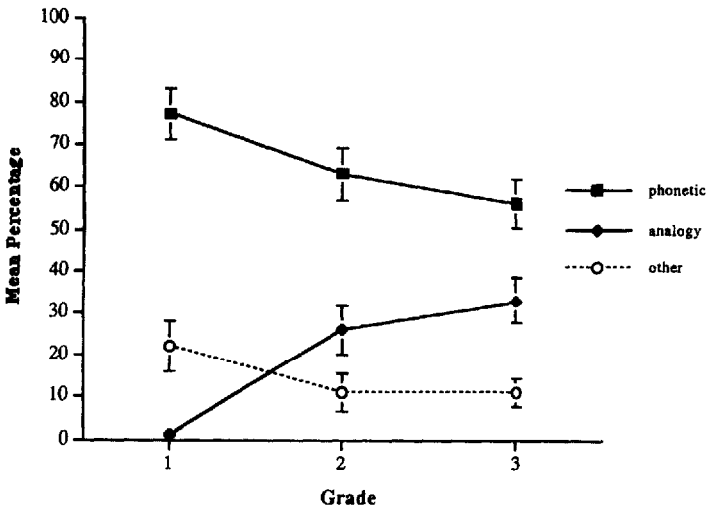

FIGURE 2 Mean percentage of strategy reports (with *SE*) by grade and strategy type.

cies that could be compared; (b) children who did report using both strategies spelled different numbers of nonwords, ranging from 1 to 14, and this leads to a lack of stability of using either a mean or a median to summarize the latencies for each child; and (c) as expected, the older children had shorter latencies, increasing variability in the measures. However, examination of average latencies computed several different ways (e.g., based on median latencies for each participant, calculated separately for o-convention and a-convention nonwords) consistently revealed faster latencies associated with analogy strategy reports.

Children's analogies to real words were examined as a function of grade and orthographic convention. If a-convention nonwords require use of orthographic information to represent them with an *a*, we might expect greater use of analogy for a-convention nonwords than for o-convention nonwords that can be easily spelled using phonological information alone. To investigate this hypothesis, we analyzed the percentage of analogy strategies reported for *a* spellings of a-convention nonwords and *o* spellings of o-convention nonwords.

Because Grade 1 children almost never reported analogy strategies, they were not included in the analysis. In addition, not all children in Grades 2 and 3 produced the appropriate spellings for a-convention or o-convention nonwords: 14 Grade 2 children and 10 Grade 3 children only produced *o* spellings (i.e., they did not produce any plausible *a* spellings for a-convention nonwords), 2 Grade 2 children and 1 Grade 3 child only produced *a* spellings (i.e., they did not produce any plausible *o* spellings to o-convention nonwords), and 19 and 24 Grade 2 and 3 children, respectively, produced both types of spellings.

We examined strategy reports by the subset of children who produced both *a* and *o* spellings. Percentage of children's analogy strategy reports accompanying *a* spellings for a-convention nonwords and *o* spellings of o-convention nonwords was analyzed in a 1 between-subject (grade) × 1 within-subjects (orthographic convention) repeated measures ANOVA.

As with the analysis of overall strategy use, we obtained a significant effect of grade, $F(1, 41) = 4.44$, $p < .05$. Grade 3 children reported using analogy more frequently ($M = 48\%$, $SE = 5\%$) than Grade 2 children ($M = 27\%$, $SE = 6\%$).

We did not obtain a significant effect of orthographic convention but we did obtain a significant interaction between grade and orthographic convention, $F(1, 41) = 7.63$, $p < .01$. Although the pattern was consistent with our hypothesis that children would increasingly use orthographic information to spell a-convention nonwords, analogy strategy reports for a-convention nonwords did not increase statistically significantly from Grade 2 ($M = 34\%$, $SE = 10\%$) to Grade 3 ($M = 41\%$, $SE = 8\%$). On the other hand, analogy reports for o-convention nonwords did increase statistically significantly ($M = 20\%$ and 54%, $SE = 6\%$ and 7% for Grades 2 and 3, respectively), HSD = 20%, $p < .05$. This finding is corroborated by analysis of the larger samples separately for a-convention and o-convention nonwords: Analogy reports increased slightly for a-convention nonwords from Grade 2 ($M =$

36%, $SE = 9\%$) to Grade 3 ($M = 40\%$, $SE = 8\%$) for a-convention nonwords, and increased more for o-convention nonwords ($M = 17\%$ and 41%, $SE = 5\%$ and 6% for Grades 2 and 3, respectively), $t(65) = 3.15$, $p < .05$.

What about children who don't show sensitivity to orthographic conventions in their spellings—do they also show an increase in use of analogy? Or do children only begin to use analogy when they become sensitive to orthographic conventions? To determine any difference in spelling strategies reported by children who used only *o* to represent /ɑ/ versus children who are sensitive to the orthographic structure of the nonword, we compared percentage of analogy strategy reports for *o* spellings of o-convention nonwords by children who produced only *o* spellings (14 Grade 2 and 10 Grade 3 children) with reports by children who produced both types of spellings (the 19 Grade 2 and 24 Grade 3 children from the previous analysis).

Results of a two-way ANOVA considering grade and spelling group (*o* vs. both *o* and *a* spellings), revealed statistically significant effects of grade, $F(1, 63) = 7.35$, $p < .05$; spelling group, $F(1, 63) = 13.34$, $p < .05$; and an interaction between grade and spelling group, $F(1, 63) = 7.35$, $p < .05$. The grade effect was comparable to the grade effects described previously. Decomposing the spelling group effect, children who produced both *o* and *a* spellings reported using analogy ($M = 39\%$, $SE = 5\%$) more than children who only produced *o* spellings ($M = 11\%$, $SE = 4\%$).

The interaction is shown in Figure 3. Grade 2 children did not differ in their use of analogy but Grade 3 children who used both *o* and *a* in their spellings were much more likely to use analogy than children who only used *o*, HSD = 25.3%, $p < .05$.

Although too infrequent to analyze, it is interesting to note that, even though the vast majority of the analogies were made to phonologically similar real words

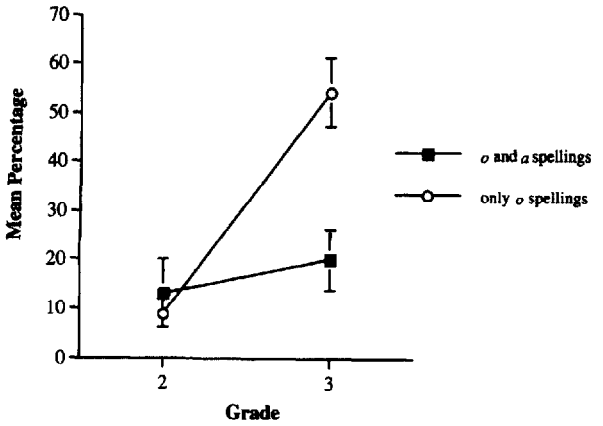

FIGURE 3 Mean percentage of analogy strategy reports (with *SE*) for Grade 2 and 3 children who used only *o* and children who used both *o* and *a* in their spelling.

(e.g., reporting spelling /nɑst/ by analogy to *cost* or spelling /nɑlt/ by analogy to *salt*), a few analogies for o-convention nonwords were to orthographically similar real words (e.g., reporting spelling /nɑst/ by analogy to *most*). This finding extends Goswami's (1988) finding that children are sensitive to orthographic information to indicate that some children may rely more on orthographic information than phonological information in their spelling.

DISCUSSION

The goal of this study was to investigate whether and how children use orthographic information while they spell an ambiguous vowel, /ɑ/. Grade 1 children spelled the vast majority of the nonwords with *o* and reported using a phonetic strategy to spell each nonword. Grade 2 children began spelling some nonwords according to the appropriate orthographic convention; they spelled some a-convention nonwords with an *a* and spelled virtually all o-convention nonwords with an *o*. Grade 3 children spelled as many a-convention nonwords with an *a* as with an *o* and continued spelling all o-convention nonwords with an *o*.

This increase in use of orthographically appropriate vowels to represent the /ɑ/ phoneme was accompanied by an increased reporting of analogy strategies. Grade 1 children seldom reported using analogy, Grade 2 children reported some use of analogy, and Grade 3 children reported using analogy about as frequently as phonetic strategies. As well, Grade 3 children who demonstrated orthographic sensitivity in their spellings (by spelling a-convention nonwords with an *a* and o-convention nonwords with an *o*) were much more likely to report analogy than children who did not demonstrate orthographic sensitivity (by spelling all nonwords with an *o*). These results need to be interpreted with some caution, however. Although we used typing latencies to support strategy reports, it could be that the younger children were making an implicit analogy to a known word while sounding out.

Recognizing this caution, our findings indicate a developmental trend from sounding out toward spelling /ɑ/ according to the appropriate orthographic convention. In addition, they indicate that children must be sensitive to orthographic conventions before they begin explicitly using analogy to real words to choose the appropriate vowel letter.

Goswami (1988) and Deavers and Brown (1997) found that Grade 2 children were more likely than Grade 1 children to spontaneously produce nonword spellings that were analogous to real words. Our findings support their results and extend them to demonstrate that older children who consistently use orthographic information in their spelling are able to verbalize their use of orthographic information.

Combining these findings with those of previous investigators (e.g., Bradley, 1988; Deavers & Brown, 1997; Frith, 1985; Goswami, 1988; Johnson & Siegler, 1999; Steffler,

Varnhagen, et al., 1998), we suggest the following pattern of development in children's spontaneous use of phonological and orthographic information in spelling vowels.

Phonological information alone is sufficient for spelling words with one-to-one, phoneme-to-grapheme mapping. If this one-to-one mapping is not possible, children must rely on other information, such as knowledge about orthographic conventions, to represent sounds with letters. Beginning spellers may not have sufficient orthographic understanding, however, and therefore may rely solely on phonology. For example, the phoneme, /ɑ/, does not have a specific letter representation but it is commonly spelled with an *o* (e.g., *slop, fox*) or an *a* (e.g., *swamp, water*); other legal spellings include *a*Ce (e.g., *are*) and, in some dialects, *ou* (e.g., *our*). Young children may not have experienced all of these different written forms of /ɑ/ but they have heard them. /ɑ/ is pronounced toward the back of the mouth, like /o/ (e.g., *coat, oh*), and this phonological similarity may account for why beginning spellers are more likely to represent /ɑ/ with an *o* than with any other vowel letter. This is consistent with our Grade 1 results and those of others (Deavers & Brown, 1997; Goswami, 1988).

As children encounter more instances of an ambiguous vowel phoneme, they may begin to recognize that the vowel phoneme can be represented in more than one way. For example, children may "sound out" /ɑ/ as *o* or as *a* somewhat indiscriminately—that is, without specific consideration of orthographic convention, such as spelling *swan* with an *a* and *swamp* with an *o*. This would explain why Grade 2 and 3 children in our study who were beginning to show sensitivity to orthographic convention spelled some of the a-convention nonwords with an *a* and some with an *o*. Treiman (1993) obtained similar results with Grade 1 children; her children seldom spontaneously spelled o-convention words with an *a* but were equally likely to spell a-convention words with an *o* as with an *a*.

Once children begin to recognize the regularity inherent in an orthographic convention, they use orthographic information to spell by analogy rather than relying on phonological information alone. This use of orthographic information occurred first with o-convention nonwords in our study, even though a-convention words theoretically may be more likely to be spelled by analogy. Children may have begun to use orthographic analogies with o-convention nonwords because these were more familiar types of spellings. Nation (1997) found a similar trend in the use of orthographic analogy as a function of word frequency; in her study, Grade 3 and 4 children were more likely to spell nonwords correctly if they had many real word neighbors (e.g., the nonword /bɪk/ has 23 monosyllable real word rime neighbors, including *pick, tick, kick, flick*) than if they had few real word neighbors (e.g., the nonword /tɪsk/ has only three real word rime neighbors, namely, *whisk, disk*, and *risk*).

Our suggestion that children progress from using phonological to incorporating orthographic information in their vowel choices in no way implies a stage model. Goswami (1988) and Deavers and Brown (1997) found that even very young children could use analogy when provided with "clues" to use analogy. Nation's

(1997) findings regarding an increase in correct spelling of nonwords as a function of number of real word neighbors also supports a continuous development model rather than a stage model. An interesting extension to this study would be to cue children into the orthographic conventions used to construct the nonwords and examine whether the children are then more likely to apply and report orthographic analogies at younger ages.

Instead, this model is clearly consistent with the connectionist models that are increasingly being used to describe spelling development (Brown & Loosemore, 1994; Nation, 1997; Nation & Hulme, 1996). A connectionist framework for vowel spelling choice consists of connections between phonological input and orthographic output units for representing vowel phonemes. These connections represent relations between the phonological and orthographic units that are developed and modified by experience. Young children and beginning spellers would have limited information associated with phonological input and orthographic output units. As children encounter more instances of particular vowel phonemes and their spellings, they develop and strengthen statistical relations between the vowel phonemes and their different spellings.

We are using the nonword vowel spelling task developed and investigated in this study to investigate orthographic knowledge in relation to spelling and reading (Boechler et al., 1999). In Boechler et al. we used vowel choices in the nonword spelling test as a production measure of orthographic knowledge. The goal of that research is to build on our findings regarding the use of orthographic information in vowel spelling and trace the relative contribution of phonological and orthographic skills, as measured by recognition and production tasks, to children's spelling achievement in early elementary school.

In conclusion, this study contributes to the literature on how children progress from relying on phonological information to incorporating orthographic information in their spelling. We concentrated on an ambiguous vowel phoneme in this study and the findings need to be replicated with other phonemes. Our results suggest the following progression for spelling ambiguous vowel phonemes: Beginning spellers make best-guess decisions to spell ambiguous vowels based solely on phonological information. When children accumulate more information about sound–letter correspondences, they begin to recognize different options for representing ambiguous vowels. As they acquire more sound–letter correspondence knowledge, children start to use orthographic regularities in their knowledge to spell new words by analogy.

ACKNOWLEDGMENTS

This research was supported by a Social Sciences and Humanities Research Council grant awarded to Connie K. Varnhagen. Portions of this research were presented

at the Annual Meeting of the American Educational Research Association, San Diego, CA, April 1998.

REFERENCES

Boechler, P. M., Varnhagen, C. K., & Steffler, D. J. (1999, April). *Progression from phonological to orthographic skills in children's spelling*. Poster presented at the biennial meeting of the Society for Research in Child Development, Albuquerque, NM.

Bradley, L. (1988). Making connections in learning to read and spell. *Applied Cognitive Psychology, 2*, 3–18.

Brown, G. D. A., & Loosemore, R. P. W. (1994). Normal and dyslexic spelling: A connectionist approach. In G. D. A. Brown & N. C. Ellis (Eds.), *Handbook of spelling research: Theory process and intervention* (pp. 319–335). New York: Wiley.

Carroll, J. B., Davies, P., & Richman, B. (1971). *The American Heritage word frequency book*. Boston: Houghton Mifflin.

Deavers, R. P., & Brown, G. D. A. (1997). Rules versus analogies in children's spelling: Evidence for task dependence. *Reading and Writing: An Interdisciplinary Journal, 9*, 339–361.

Ehri, L. C. (1986). Sources of difficulty in learning to spell and read. In M. L. Wolraich & D. Routh (Eds.), *Advances in developmental and behavioral pediatrics* (Vol.7, pp. 121–195). Greenwich, CT: JAI.

Ehri, L. C., Wilce, L. S., & Taylor, B. B. (1987). Children's categorization of short vowels in words and the influence of spellings. *Merrill-Palmer Quarterly, 33*, 393–421.

Frith, U. (1985). Beneath the surface of developmental dyslexia. In K. E. Patterson, J. C. Marshall, & M. Coltheart (Eds.), *Surface dyslexia* (pp. 301–330). London: Routledge & Kegan Paul.

Goswami, U. (1988). Children's use of analogy in learning to spell. *British Journal of Developmental Psychology, 6*, 21–33.

Hanna, P. R., Hanna, J. S., Hodges, R. E., & Rudorf, E. H. (1966). *Phoneme–grapheme correspondences as cues to spelling improvement* (DHEW Publication No. ADM CRP–1991). Washington, DC: U.S. Government Printing Office.

Henderson, E. H., & Beers, J. W. (Eds.). (1980). *Developmental and cognitive aspects of learning to spell: A reflection of word knowledge*. Newark, DE: International Reading Association.

Johnson, B. R., & Siegler, R. S. (1999). Learning to spell: Variability, choice, change in strategy use. *Child Development, 70*, 332–348.

Kessler, B., & Treiman, R. (1997). Syllable structure and the distribution of phonemes in English syllables. *Journal of Memory and Language, 37*, 295–311.

Nation, K. (1997). Children's sensitivity to rime unit frequency when spelling words and nonwords. *Reading and Writing: An Interdisciplinary Journal, 9*, 321–338.

Nation, K., & Hulme, C. (1996). The automatic activation of letter–sound knowledge: An alternative interpretation of analogy and priming effects in early spelling development. *Journal of Experimental Child Psychology, 63*, 416–435.

Read, C. (1975). *Children's categorization of speech sounds in English* (NCTE Research Rep. No. 17). Urbana, IL: National Council of Teachers of English.

Stage, S. A., & Wagner, R. K. (1992). Development of young children's phonological and orthographic knowledge as revealed by their spellings. *Developmental Psychology, 28*, 287–296.

Steffler, D. J., Varnhagen, C. K., & Boechler, P. M. (1998, April). *The diversity and adaptability of children's spelling strategies*. Poster presented at the annual meeting of the American Educational Research Association, San Diego, CA.

Steffler, D. J., Varnhagen, C. K., Friesen, C. K., & Treiman, R. (1998). There's more to children's spelling than the errors they make: Strategic and automatic processes for one-syllable words. *Journal of Educational Psychology, 90*, 492–505.

Templeton, S., & Bear, D. R. (Eds.). (1992). *Development of orthographic knowledge and the foundations of literacy: A memorial festschrift for Edmund H. Henderson.* Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Treiman, R. (1993). *Beginning to spell.* New York: Oxford University Press.

Treiman, R., Mullennix, J., Bijeljac-Babic, R., & Richmond-Welty, E. D. (1995). The special role of rimes in the description, use, and acquisition of English orthography. *Journal of Experimental Psychology: General, 124,* 107–136.

Manuscript received August 5, 1998
Final revision received January 21, 1999
Accepted February 2, 1999

APPENDIX

Target Nonwords, Four-Phoneme Real-Word Onset and Coda Neighbors, With Average Grade 3 Word Frequency in Parentheses (Carroll et al., 1971)

Real Word Neighbors

O-Convention Nonwords
Onset-Controlled
/slak/,/slad/, /sas/, /slaf/

Onset Neighbors		Coda Neighbors	
a Spellings	*o* Spellings	*a* Spellings	*o* Spellings
slav (-)	slob (0)	fraud (0)	clock (80)
	slop (2)		frock (0)
	slosh (0)		stock (12)
	sloth (9)		flock (18)
	slot (14)		smock (0)
	slog (0)		cross (116)
			gloss (1)
			floss (–)
			scoff (0)
			clod (–)
			prod (0)
			trod(1)
			plod(1)

Coda-Controlled
/nɑst/, /gɑst/, /rɑst/, /dɑst/

Onset Neighbors		Coda Neighbors	
a Spellings	*o* Spellings	*a* Spellings	*o* Spellings
garb (0)	dodge (2)	—	cost (118)
darn (0)	notch (3)		lost (149)
dart (5)	nonce (–)		
dark (254)	romp (0)		

A-Convention Nonwords
Onset-Controlled
/swɑk/, /swɑd/, /swɑs/, /swɑf/

Onset Neighbors		Coda Neighbors	
a Spellings	*o* Spellings	*a* Spellings	*o* Spellings
swab (0)	—	—	clock (80)
swap (8)			frock (0)
swat (0)			stock (12)
swath (1)			flock (18)
swan (24)			smock (0)
swash (3)			cross (116)
			gloss (1)
			floss (–)
			scoff (0)
			clod (–)
			prod (0)
			trod(1)
			plod(1)

A-Convention Nonwords
Coda-Controlled
/nɑlt/, /gɑlt/, /rɑlt/, /dɑlt/

Onset Neighbors		Coda Neighbors	
a Spellings	*o* Spellings	*a* Spellings	*o* Spellings
garb (0)	dodge (2)	halt (2)	—
darn (0)	notch (3)	salt (134)	
dart (5)	nonce (–)	malt (2)	
dark (254)	romp (0)		