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# Emergent literacy skills and training time uniquely predict variability in responses to phonemic awareness training in disadvantaged kindergartners

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**Abstract**

The factors that predicted variability in responses to phonemic awareness training were investigated in kindergartners who live in poverty. Treatment children ($n = 42$) received both analytic and synthetic phonemic awareness computer-assisted instruction, while controls ($n = 34$) received no special training. Mean age of participants was approximately 5 years 7 months. Pretests included initial phonemic awareness, letter knowledge, word-level reading, invented spelling, vocabulary knowledge, and print concepts. Spelling skills emerged as the best consistent predictor of variability in phonemic awareness in response to instruction. We propose that relations between phonemic awareness and spelling skills are bidirectional: Spelling influenced growth in phonemic awareness and phonemic awareness contributed to growth in spelling skills. The amount of exposure that children had to the treatment intervention contributed uniquely to individual differences in posttest levels of phonemic awareness and spelling. © 2002 Elsevier Science (USA). All rights reserved.

*Keywords:* Preventing reading failure; Phonological awareness; Phonemic awareness; Computer-assisted instruction

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Children who live in poverty are more likely to develop reading and spelling impairments when compared to children from more affluent home backgrounds (Bowey, 1995; Hecht, Burgess, Torgesen, Wagner, & Rashotte, 2000; Nicholson, 1997). Certain kinds of phonological abilities causally influence growth in reading and spelling and should therefore be targeted in early interventions designed to prevent academic failure (Blachman, 1997). Of these phonological processing abilities, phonemic awareness is an important source of variability in reading and spelling (see, e.g., Brady & Shankweiler, 1991; Treiman, 1991; Wagner et al., 1997). Phonemic awareness includes the ability to identify sounds within words and being able to blend speech segments into words.

As a group, children who live in poverty show lower levels of phonemic awareness when compared to more affluent peers (Hecht & Greenfield, 2001; Nicholson, 1997). Evidence about the central role of phonemic awareness in reading and spelling acquisition suggests that early interventions must contain powerful instruction in phonemic awareness (Blachman, 1997). In fact, teacher-led instruction can improve average levels of phonemic awareness in disadvantaged children (e.g., Nicholson, 1997; Torgesen et al., 1999).

Computer-assisted instruction is a relatively new and promising approach for teaching phonemic awareness (Foster, Erickson, Foster, Brinkman, & Torgesen, 1994; Torgesen & Barker, 1995). Sophisticated capabilities of computers that are relevant to instruction in phonemic awareness are now widely available. These features include digitized speech and high-quality graphics, immediate feedback, and gamelike presentation of lessons to maintain student interest (Mioduser, Tur-Kaspa, & Leitner, 2000). Computer-assisted instruction can provide training while requiring minimal teacher or aid time. Also, the provided instruction is less likely to vary from classroom to classroom depending on teacher level of training or interest (Foster et al., 1994). Two studies reported positive effects of this kind of training on average levels of phonemic awareness in kindergartners (see Foster et al., 1994; Reitsma & Wessling, 1998).

Determining whether phonemic awareness training will be a useful intervention for particular individual children is difficult because very little is known about variability in response to this training (cf. Torgesen, 2000; Vellutino et al., 1996). Children differ in terms of how much they profit from phonemic awareness instruction; so-called "treatment resisters" do not seem to benefit much from effective training (Torgesen, 2000; Torgesen et al., 1999). For example, Torgesen and Davis (1996) reported that approximately 35% of the children who received phonemic awareness training received a score of zero or one on posttest segmenting. Research is clearly needed to identify child characteristics before an intervention that can enhance individual responses to phonemic awareness instruction.

The purpose of the present study was to address this issue by focusing on three related questions concerning prediction of variability in responses to phonemic awareness instruction in kindergarteners who live in poverty. Children received computer-assisted instruction via the Waterford Early Reading Program, Level One (WERP-1). The WERP-1 is designed to enhance early emergent literacy skills in prereaders and kindergarteners, particularly analytic and synthetic phonemic awareness (Alfaro, 1999; Waterford Institute, 1999, 2000). The first question asked whether children's initial emergent literacy skills before training could influence growth in phonemic awareness in response to the phonemic awareness intervention. The second question asked whether children's initial reading-related abilities could explain growth in the other emergent literacy skills included in this study. The third question asked whether the amount of time that children received phonemic awareness training uniquely influenced emergent literacy outcomes independently of initial reading-related skills and vice versa.

## Initial emergent literacy skills and growth in phonemic awareness

Emergent literacy skills refer to skills and knowledge that are developmental precursors of fluent word reading and writing ability (Crone & Whitehurst, 1999). In the beginning of kindergarten, children show considerable variability in levels of emergent literacy skills (Whitehurst & Lonigan, 1998). In this study, we measured specific kinds of emergent literacy skills that may help children benefit from phonemic awareness training. We measured initial phonemic awareness and letter knowledge. Levels of phonemic awareness before training starts should provide a starting point for children to build additional capacity for reflecting on the sound structure of oral language. Knowing the sounds that letters make in words should require focus on individual speech sounds (Griffith, 1991). Similarly, knowing the names of individual letters is associated with learning corresponding letter sounds (McBride-Chang, 1999), perhaps because letter names usually include a similar sound as the phoneme represented in words by that letter. Letter knowledge is an important precursor of phonemic awareness (Johnston, Anderson, & Holligan, 1996) and influences early growth in both phonemic analysis and synthesis skills (Wagner, Torgesen, & Rashotte, 1994).

We also measured children's vocabulary knowledge and invented spelling. Vocabulary knowledge correlates substantially with measures of phonological segmenting and blending (Wagner, Torgesen, Laughon, Simmons, & Rashotte, 1993), in part because a well-developed vocabulary may be useful during on-line phonemic awareness performance when the child attempts to match candidate answers to known words. Young children often "invent" spellings based on the sounds they hear within the word (e.g., "will" spelled “wil”). Such invented spellings are related to phonemic awareness in middle-class kindergarteners (McBride-Chang, 1998).

We also assessed print concepts, which involve children’s understandings of the conventions of print (e.g., book handling skills, where to begin reading a sentence, and what a period is used for; Adams, 1990; Clay, 1993). Print concept knowledge reflects children’s exposure to books and reading-related interactions with adults (Shatil, Share, & Levin, 2000; Whitehurst et al., 1994). Presumably, kindergarten children with well-developed print concept knowledge are exposed to a variety of activities that can positively influence emergent literacy skills, including phonemic awareness (Frijters, Barron, & Brunello, 2000; Lonigan, 1998).

To our knowledge, only a study by Torgesen and Davis (1996) provides relevant data regarding the characteristics of kindergarten children who live in poverty before an intervention that can be predictive of emerging variability in phonemic awareness. Pretest levels of performance on the phonemic awareness, letter knowledge, invented spelling, and vocabulary knowledge tasks were associated with growth in both phonemic segmenting and blending skills. Interestingly, spelling emerged as an independent predictor of variability in phonemic awareness growth rates while controlling for the other pretested skills. Torgesen and Davis (1996) concluded that invented spelling was the best consistent predictor of growth in both phonemic blending and segmenting. In the current study, we also looked at whether pretested emergent literacy skills predicted later variability in phonemic awareness.

## Initial emergent literacy skills and growth in invented spelling, word reading, letter knowledge, print concepts, and vocabulary knowledge

The second question asked whether children’s initial reading-related abilities could explain growth in the other emergent literacy skills included in this study. That is, we examined whether pretested abilities influenced growth in invented spelling, word reading, letter knowledge, print concepts, and vocabulary knowledge.

Phonemic awareness training should enhance children’s invented spelling (Ball & Blachman, 1991; Tangel & Blachman, 1992). As mentioned previously, the mental operations required for invented spelling and phonemic awareness tasks overlap considerably. Indeed, some have argued that invented spelling can be used to measure phonemic awareness (Mann, Tobin, & Wilson, 1987). Thus, interventions that enhance phonemic awareness should also have some impact on spelling. We expected that initial levels of letter knowledge and phonemic awareness would predict growth in invented spelling. Children need to know about the sounds that letters represent in order to write words. Explicit awareness of speech sounds and relationships among phonemes should help children invent spellings (Mann et al., 1987; Tangel & Blachman, 1992).

Although the current phonemic awareness training did not include explicit instruction in word level reading, we assumed some generalization of this training to decoding (Ball & Blachman, 1991; Fuchs et al., 2001). Phonemic awareness skills are necessarily important for decoding acquisition (Brady & Shankweiler, 1991; Tunmer & Nesdale, 1985). Thus, we expected that pretested levels of phonemic awareness would be the most powerful predictor of any growth in word level reading in response to phonemic awareness instruction. Finally, we predicted that initial levels of print concepts would predict growth in letter knowledge and vocabulary. Children who are exposed to reading-related experiences and opportunities should be in a better position to acquire letter knowledge and vocabulary than those not provided much literacy experiences (Lonigan, 1998).

## Training time and growth in emergent literacy skills

The third question asked whether the amount of time that children received phonemic awareness training uniquely influenced emergent literacy outcomes independently of initial reading-related skills and vice versa. The WERP-1 software recorded the amount of time that children were engaged in the training. Training time might vary drastically from child to child, even in small teacher-led groups within the same session. The effectiveness of literacy-related interventions should be substantially influenced by how much children actually experience the training (Whitehurst et al., 1994). Thus, variability in phonemic awareness training time may uniquely influence posttest levels of emergent literacy skills. Initial emergent literacy skills may contribute to growth in literacy-related outcomes while controlling for training time. This result would suggest that initial levels of performance contribute to growth in emergent literacy skills regardless of the amounts of phonemic awareness training that children received.

## Method

### *Participants*

The Waterford Early Reading Program (WERP-1) treatment group was composed of 42 kindergartners. The control children were 34 kindergartners who were given not special phonemic awareness training. The WERP-1 treatment group children were randomly selected from four different public schools, while control children were randomly selected from two other public schools. Understandably, teachers were reluctant to deny any child access to the WERP-1. Thus, it was necessary to obtain control children from schools that did not have the WERP-1 in any classroom in order to ensure that these children received no exposure to the WERP-1. Children attended inner city or rural public schools serving students from primarily low-SES and racial minority (African American) families.

### *Materials*

Participants in both samples were individually administered tests that assess phonemic segmenting and blending, word reading, letter name and sound knowledge, print concepts, invented spelling, and vocabulary knowledge.

There were two measures of phonemic awareness.

1. *Phonemic segmenting*. This was our measure of phonemic analysis skills, which was taken from the Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen, & Rashotte, 2000). Children listened to words and were instructed to "... tell me each sound you hear in the word in the order that you hear it." There were three practice items for which feedback was given, and 15 test items consisting of two to five phoneme single-syllable words. Total number of words correctly pronounced one phoneme at a time was recorded.

2. *Phonemic blending*. This was our measure of phonemic synthesis skills, which was taken from the CTOPP. Children listened to phonemes presented one at a time and were asked to say the word that was produced when the sounds were combined. There were four practice items wherein feedback was given. The 15 test items consisted of two- to four-phoneme, one- and two-syllable words. Total number of words correctly spoken was recorded.

There were three measures of letter knowledge.

3. *Letter name knowledge*. Children were presented each of the 26 capital letters in random order and were asked to pronounce the name of the letter. Total number of letter names correctly pronounced was recorded.

4. *Letter sound knowledge*. Children were shown each of the 26 capital letters in random order and were asked to pronounce the sound that the letter makes in words. Total number of letter sounds correctly pronounced was recorded.

5. *Letter writing knowledge*. This task came from the Spelling subtest from the Wide Range Achievement Test (Wilkinson, 1995). Children were asked to write 15 letters uttered by the experimenter on a sheet of paper. Total number of correctly written letters was recorded.

There was one measure of word level reading.

6. *Word reading*. Children were administered the Letter Word Identification subtest from the Woodcock–Johnson Tests of Achievement—Revised (Form B) (Woodcock & Johnson, 1990). Words were presented one at a time, and total number of words correctly read was recorded.

There was one measure of invented spelling skills.

7. *Invented spelling*. This task came from the Spelling subtest from the Wide Range Achievement Test (Wilkinson, 1995). Children were asked to write 15 words uttered by the experimenter on a sheet of paper. Children's invented spellings of words were scored, based on Wilkinson's (1995) method of giving partial credit, in order to measure accuracy of phonemic representations in spelling. A score of 0–6 was calculated for each item, using the following criteria: zero points for a random string with no phonetically related letters (e.g., "zrg" for "cat"); 1 point if spelling contained any single phonetically related or conventional letter, but not the correct initial phoneme (e.g., "rxt" for "cat"); 2 points if spelling represented the correct initial phoneme, whether or not followed by a random string (e.g., "cbr" for "cat"); 3 points if spelling showed more than one phoneme represented (but not all) with phonetically related or conventional letters (e.g., "ktb" for "cat"); 4 points for all phonemes represented with mix of phonetically related letters and conventional letters (e.g., "tren" for "train"); 5 points for all phonemes represented with mix of phonetically correct letters and conventional letters (e.g., "kat" for "cat") or nonconventional but phonetically accurate spelling of the word (e.g., "trane" for "train"); and 6 points for correct conventional spelling of word.

There was one measure of vocabulary knowledge.

8. *Vocabulary knowledge*. This was the vocabulary subtest of the Stanford–Binet: Fourth Edition (Thorndike, Hagen, & Sattler, 1986). Children uttered the definition of words. General cognitive ability is typically assessed with a brief vocabulary measure that has established concurrent validity with standard tests of verbal IQ (Sattler, 1988; Tunmer & Nesdale, 1985; Wagner et al., 1993). The Stanford–Binet vocabulary subtest is the most highly correlated subtest with overall verbal IQ (Sattler, 1988). Total number of correctly defined words was recorded.

There was one measure of print concepts:

9. *Concepts about print*. Children were asked questions about books and reading. This was the Stones—Concepts About Print Test (Clay, 1979). Children were asked 18 questions concerning their knowledge about print (e.g., where the front of a book is). Total number of correct items was recorded.

## *Procedure and description of training*

Tasks were administered in random order for each participant. The pretesting was done in the fall of children's kindergarten year and again in the spring of their kindergarten year. The duration of time between the pre- and posttest time periods was approximately 6 months. Master's graduate students, in a quiet location on school grounds, administered the tests to each child individually.

The Waterford Early Reading Program trained children received the computer-assisted instruction as part of the normal educational practices in their classroom for approximately 6 months. Children received the WERP-1, which is designed for prereaders and kindergartners. The Waterford multimedia computer learning stations were housed in their classroom. Each student worked individually at the computer for at least approximately 15 min per session, interacting with a carefully sequenced mix of activities. The software includes approximately 900 separate activities and a teacher management system that includes daily usage in time. The software uses high-quality digitized speech for instructions, song activities, and presentation of visual stimuli. It also features colorful graphic displays that help to motivate performances in a gamelike setting. The program includes a heavy concentration on phonological awareness skills and also includes daily activities that focus on letter knowledge, print concepts, and oral language skills. It is important to note that practice in word-level decoding skills is not explicitly given by the WERP-1. Daily phonemic awareness activities include matching pictures on the basis of first sounds, phoneme deletion wherein students determine which word remains when the beginning sound is removed, and blending individual sounds into words with the aid of a "blending dragon." Students also practiced rhyming, such as by matching pictures based on common rhymes, choosing a word to complete a rhyming story, and singing a song that illustrates rhyming words. Daily letter knowledge tasks included sing-along activities that display letters while teaching the letter names and sounds. Children acquired print concept knowledge during activities involving presentation of stories on graphically reproduced book pages. Additional details regarding the WERP-1 can be found in Waterford Institute (1999, 2000). Children in the control group received no special intervention. Following Torgesen and Davis (1996), the control group was included in this study primarily as a benchmark against which to compare the growth in outcomes of the training group.

All children received the bulk of their daily literacy-related instruction via teacher-led activities. There appeared to be no systematic differences between groups in the instructional approach taken by classroom teachers. Literacy-related activities were primarily literature based and guided by a whole-language philosophy.

## Results

### *Descriptive statistics*

Pre- and posttest descriptive statistics for both the WERP-1 and control groups can be found in Table 1. Unless otherwise indicated, Cronbach's $\alpha$ statistical reliability is presented for each task. We determined the age-based

Table 1
Descriptive statistics for all tasks

| Pretest predictors | Training ($n = 42$) | | | Control ($n = 34$) | | |
|---|---|---|---|---|---|---|
| | *M* | *SD* | Reliability | *M* | *SD* | Reliability |
| Segmenting | | | | | | |
| Pre | 1.76 | 3.31 | .91 | 1.44 | 2.43 | .88 |
| Post | 7.91 | 7.05 | .95 | 1.53 | 2.84 | .91 |
| Gain | 6.14*** | 6.09 | — | .09 | 1.50 | — |
| Blending | | | | | | |
| Pre | 4.98 | 5.01 | .95 | 3.65 | 3.27 | .85 |
| Post | 10.29 | 5.55 | .93 | 4.24 | 5.08 | .94 |
| Gain | 5.31*** | 5.94 | — | .59 | 3.49 | — |
| Letter name knowledge | | | | | | |
| Pre | 19.45 | 8.52 | .97 | 16.82 | 9.82 | .95 |
| Post | 24.21 | 4.43 | .98 | 24.65 | 4.14 | .93 |
| Gain | 4.76*** | 7.16 | — | 7.83*** | 8.07 | — |
| Letter sound knowledge | | | | | | |
| Pre | 19.51 | 11.04 | .96 | 13.79 | 11.45 | .97 |
| Post | 24.81 | 8.87 | .95 | 22.55 | 9.33 | .92 |
| Gain | 5.30*** | 10.92 | — | 8.76*** | 9.06 | — |
| Letter writing knowledge | | | | | | |
| Pre | 6.95 | 4.99 | .94 | 5.41 | 4.41 | .96 |
| Post | 12.00 | 2.35 | .94 | 11.21 | 3.49 | .98 |
| Gain | 5.05*** | 4.54 | — | 5.79*** | 4.46 | — |
| Word reading | | | | | | |
| Pre | .40 | .80 | .55 | .12 | .41 | .84 |
| Post | 3.72 | 3.43 | .91 | .77 | 1.16 | .72 |
| Gain | 3.32*** | 3.20 | — | .65** | 1.27 | — |
| Invented spelling | | | | | | |
| Pre | 3.55 | 4.28 | .96[a] | 2.41 | 3.84 | .98[a] |
| Post | 26.71 | 19.67 | .91[a] | 8.09 | 7.79 | .94[a] |
| Gain | 23.16*** | 17.75 | — | 5.68*** | 5.77 | — |
| Vocabulary knowledge | | | | | | |
| Pre | 16.50 | 3.42 | .88 | 15.60 | 6.07 | .82 |
| Post | 17.41 | 3.66 | .79 | 16.58 | 3.35 | .95 |
| Gain | .91 | 3.45 | — | .58 | 2.34 | — |
| Print concepts | | | | | | |
| Pre | 7.83 | 2.92 | .74 | 6.53 | 3.30 | .79 |
| Post | 9.88 | 3.05 | .84 | 9.01 | 4.57 | .91 |
| Gain | 2.05*** | 2.79 | — | 2.48*** | 4.34 | — |
| Total time spent using the WERP-1 (hours:minutes: seconds) | 21:25:49 | | | | 7:17:38 | |

[a] Proportion of agreement between two independent raters.
** $p < .01$.
*** $p < .001$.

standard scores for vocabulary knowledge, which is a subtest of the Stanford–Binet Intelligence Scale: Fourth Edition (not shown in Table 1). The age-based standard scores for each group at each time point ranged from between approximately 94–102. These values are within the "average" range for the vocabulary task, which is scaled from a distribution with a mean of 100 and standard deviation of 15.

Group differences in pretested performance were evaluated. The multivariate ANOVA indicated that the overall model was not significant, $F(9,66) = 1.05$, $p > .10$. Follow-up ANOVAs indicated that pretested performance for letter sound knowledge was significantly higher for the WERP-1 treatment group than the control group, $F(1,74) = 5.833$, $p < .05$. No other pretest differences were found.

*Effects of phonemic awareness training*

We first examined whether children who received WERP-1 computer-assisted instruction performed better on the posttest measures of phonemic awareness. With the respective pretest scores as covariates, training effects for both phonemic segmenting and blending were examined via analysis of covariance. Significant effects of training emerged for both phonemic segmenting, $F(1,73) = 27.463$, $p < .001$, and blending, $F(1,73) = 18.426$, $p < .001$. Indeed, even when all pretested emergent literacy skills were considered as covariates, posttest levels of phonemic awareness were greater than the control group for segmenting, $F(1,66) = 25.605$, $p < .001$, and blending, $F(1,66) = 17.201$, $p < .001$. The important effects of the WERP-1 on phonemic awareness skills was also apparent when pre- to posttest gain scores (i.e., posttest minus pretest performance) were examined (see Table 1). That is, performance significantly increased between the pre- and posttest time periods for both blending and segmenting for WERP-1 children. Meanwhile, control children made no improvements ($p's > .10$) in phonemic awareness between the pre- to posttest periods.

Effect sizes were computed in order to make comparisons regarding the effects of training between the current data set and the Torgesen and Davis (1996) results. Concerning the Torgesen and Davis results, the effect sizes for group differences in phonemic segmenting and blending skills were .784 and 1.39, respectively. These effect sizes were comparable to the findings from the new WERP-1 data set. We found that effect sizes for group differences between the WERP-1 and control children were 1.14 and 1.13 for segmenting and blending skills, respectively. Effect sizes of .80 or higher suggest large effects (Cohen, 1988; Murphy & Myors, 1998). These results provide important evidence that computer-assisted instruction can enhance phonemic awareness skills similarly to teacher-led tutoring sessions.

We next examined posttest differences between the WERP-1 treatment and control groups with respect to the other emergent literacy skills.

With the respective pretest scores as covariates, reliable training effects emerged for word reading, $F(1,73) = 20.207$, $p < .001$, effect size = 1.114; and invented spelling, $F(1,73) = 26.113$, $p < .001$, effect size = 1.198. It should be noted that group differences in invented spelling did not emerge because control children were less able to write letters on paper than the WERP students. Group differences did not emerge for letter writing, letter name, or letter sound knowledge, vocabulary knowledge, or print concepts ($p's > .10$).

### *Initial emergent literacy skills and growth in phonemic awareness*

The first research question addressed by this study concerned whether children's initial emergent literacy skills contributed to how well children could segment and blend phonemes after effective phonemic awareness instruction. We examined predictors of growth in phonemic awareness skills using multiple regression.

All analyses were performed using hierarchical regression procedures (i.e., forced entry of predictors in steps) using the WERP-1 treatment group data. The pretest predictors were word level reading, invented spelling, vocabulary knowledge, print concepts, phonemic awareness, and letter knowledge. We employed two measures of phonemic awareness (i.e., phonemic blending and segmenting) and three tasks for letter knowledge (i.e., letter writing, letter name, and letter sound knowledge). We constructed unit-weighted composite variables for phonemic awareness and letter knowledge in order to minimize the number of predictors included in the multiple-regression analyses. Phonemic awareness tasks capture, in large part, a common phonemic awareness construct in young children (see, e.g., Stanovich, Cunningham, & Cramer, 1984; Wagner et al., 1997; Yopp, 1988). Statistical reliabilities (Cronbach's $\alpha$s) were computed based on all phonemic awareness items (i.e., all phonemic blending and segmenting items). Likewise, pre- and posttest reliabilities for all of the letter knowledge items (i.e., all letter writing, letter name, and letter sound knowledge items) were computed. For both the control and WERP-1 children, the statistical reliabilities were all greater than .87, which provides empirical support for combining these measures into composites. Statistical reliabilities that are .80 or higher suggest that items tap, in large part, the same fund of knowledge or skill (Traub, 1994). Bivariate correlations for all variables used in the regression analyses are reported in Table 2.

The first panel in Table 3 (i.e., Step 1) depicts the proportion of variance in later phonemic awareness that was explained by pretested levels of ability. Prior ability was significantly associated with variability in posttest phonemic awareness, accounting for 27% of the variance in later ability. By controlling for previous ability (i.e., the autoregressor), the magnitudes of our estimates of relations between the predictors and later phonemic awareness

Table 2
Correlations among pretest and outcome variables for the WERP-1 treatment and control groups

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Phonemic awareness—pretest | — | .80 | .43 | .45 | −.04 | .41 | .39 | .66 | .33 | .44 | .28 | .27 | — |
| 2. Phonemic awareness—posttest | .52 | — | .46 | .37 | −.12 | .45 | .43 | .70 | .37 | .45 | .46 | .35 | — |
| 3. Letter knowledge—pretest | .23 | .46 | — | .63 | .05 | .31 | .30 | .53 | .13 | .36 | .55 | .46 | — |
| 4. Letter knowledge—posttest | .14 | .44 | .54 | — | .05 | .14 | .34 | .56 | .25 | .37 | .45 | .63 | — |
| 5. Word reading—pretest | .18 | .12 | .10 | .17 | — | .37 | .10 | .07 | .11 | .06 | .02 | .01 | — |
| 6. Word reading—posttest | .59 | .62 | .39 | .43 | .40 | — | .02 | .38 | .11 | .14 | .32 | .04 | — |
| 7. Invented spell—pretest | .36 | .61 | .47 | .33 | .32 | .53 | — | .55 | .49 | .30 | .22 | .39 | — |
| 8. Invented spell—posttest | .60 | .76 | .51 | .49 | .23 | .73 | .53 | — | .41 | .32 | .45 | .51 | — |
| 9. Vocabulary—pretest | .41 | .57 | .40 | .34 | .24 | .53 | .36 | .48 | — | .67 | .38 | .54 | — |
| 10. Vocabulary—posttest | .40 | .50 | .36 | .38 | .34 | .40 | .42 | .37 | .68 | — | .38 | .52 | — |
| 11. Print concepts—pretest | .38 | .56 | .61 | .56 | .15 | .45 | .31 | .54 | .61 | .55 | — | .49 | — |
| 12. Print concepts—posttest | .18 | .59 | .34 | .55 | .04 | .38 | .28 | .44 | .56 | .35 | .55 | — | — |
| 13. Time using the WERP-1 | .36 | .64 | .24 | .51 | .01 | .44 | .34 | .57 | .50 | .38 | .49 | .52 | — |

*Note*. Correlations below the diagonal represent the WERP-1 treatment group data. With a sample size of 42 for the treatment group, any correlation at or above. 29 is statistically reliable ($p < .05$). The corresponding figure for the control group, with 34 participants, is .33. Phonemic awareness refers to the unit-weighted composite variable composed of phonemic segmenting and blending. Letter knowledge refers to the unit weighted composite variable composed of the letter writing, name, and letter sound knowledge tasks.

Table 3
Emergent literacy and individual differences in responses to phonemic awareness training

| Pretest predictors | Posttest outcomes | | | | | |
|---|---|---|---|---|---|---|
| | Phonemic awareness | Invented spelling | Word reading | Letter knowledge | Print concepts | Vocabulary knowledge |
| | $R^2$ | $R^2$ | $R^2$ | $R^2$ | $R^2$ | $R^2$ |
| *Step 1: Autoregressor* | | | | | | |
| | .27*** | .29*** | .16** | .29* | .30*** | .49*** |
| *Step 2a: Each predictor entered by itself after the autoregressor* | | | | | | |
| Letter knowledge | .13** | .09* | .12** | — | .00 | .01 |
| Word reading | .01 | .00 | — | .02 | .00 | .01 |
| Invented spelling | .21*** | — | .18*** | .02 | .02 | .02 |
| Vocabulary knowledge | .16*** | .10* | .20*** | .02 | .07* | — |
| Print concepts | .15** | .08* | .12* | .08* | — | .03 |
| Phonemic awareness | — | .19*** | .27*** | .00 | .00 | .02 |
| Time using WERP-1 | .24*** | .17*** | .19*** | .14*** | .07* | .01 |
| *Step 2b: Letter knowledge, invented spelling, vocabulary knowledge, print concepts, and phonemic awareness entered together after the autoregressor* | | | | | | |
| Letter knowledge | .00 | .00 | .00 | — | .00 | .00 |
| Invented spelling | .10** | — | .04 | .00 | .00 | .01 |
| Vocabulary knowledge | .02 | .01 | .00 | .01 | .07* | — |
| Print concepts | .02 | .02 | .01 | .08* | — | .01 |
| Phonemic awareness | — | .11** | .09** | .02 | .01 | .01 |
| Total $R^2$ | .60 | .57 | .56 | .40 | .41 | .53 |
| *Step 2c: Letter knowledge, invented spelling, vocabulary knowledge, print concepts, and phonemic awareness entered together with time using the WERP-1 after the autoregressor* | | | | | | |
| Letter knowledge | .00 | .00 | .00 | — | .00 | .01 |
| Invented spelling | .07* | — | .04 | .01 | .00 | .01 |
| Vocabulary knowledge | .02 | .00 | .01 | .00 | .06* | .01 |
| Print concepts | .01 | .00 | .01 | .01 | — | — |
| Phonemic awareness | — | .09** | .08* | .00 | .00 | .01 |
| Time using WERP-1 | .08** | .06* | .02 | .10** | .06* | .01 |
| Total $R^2$ for emergent literacy | .27*** | .31** | .39*** | .25** | .19* | .53*** |
| Total $R^2$ | .68 | .63 | .58 | .50 | .47 | .54 |

*Note*. Total $R^2$ for emergent literacy refers to the total proportion of unique variance in posttest performance captured by all emergent literacy predictors, including the autoregressor, while controlling for time using the WERP-1.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

were not influenced by prior levels of phonemic awareness. In addition, by including prior ability in our analyses, we were able to predict changes in relative ordering of participant's phonemic awareness (i.e., growth) during the time point under consideration (Gollob & Reichardt, 1987; Hecht, Torgesen, Wagner, & Rashotte, 2001; Wagner et al., 1994, 1997).

The second panel in Table 3 (i.e., Step 2a) shows the proportion of variance in posttest phonemic awareness captured by each predictor after controlling for the autoregressive effect of prior ability. Letter knowledge, invented spelling, vocabulary knowledge, and print concepts emerged as reliable predictors of growth in phonemic awareness. An obvious question to address is whether relations between the pretest predictors and growth in phonemic awareness were redundant with each other. The third panel in Table 3 (i.e., Step 2b) shows the proportion of variance in later phonemic awareness skills explained after invented spelling, vocabulary knowledge, letter knowledge, and print concepts were entered into the analysis simultaneously after the autoregressor. Word reading was not included in the simultaneous analysis because it did not predict growth in any outcome, while controlling for the autoregressor. Interestingly, invented spelling emerged as a unique predictor of growth in phonemic awareness skills.

This pattern of results emerged when phonemic blending and segmenting were considered separately instead of combined into a composite variable (not shown in Table 3). That is, invented spelling emerged as the only consistent predictor of growth in both phonemic awareness outcomes while controlling for the other emergent literacy skills and the autoregressor. Specifically, invented spelling uniquely captured approximately 9 and 10% of the variance in growth of blending and segmenting skills, respectively.

We also examined whether the pretested variables predicted what little growth emerged in phonemic awareness skills for children in the control group (not shown in Table 3). Individual differences in phonemic awareness across the pre- and posttest time periods were highly consistent ($r = .80$), reflecting that control children made little progress in phonemic awareness. Not surprisingly, none of the pretest variables predicted growth in control children's phonemic awareness.

### *Initial emergent literacy skills and growth in invented spelling, word reading, letter knowledge, print concepts, and vocabulary knowledge*

The second question asked whether children's initial reading-related abilities could explain growth in the other emergent literacy skills included in this study. That is, we examined whether pretested abilities influenced growth in invented spelling, word reading, letter knowledge, print concepts, and vocabulary knowledge.

The first panel in Table 3 (i.e., Step 1) depicts the proportion of variance in later emergent literacy skills that was explained by pretested levels of ability (i.e., the autoregressor). The second panel in Table 3 (i.e., Step 2a) shows the proportion of variance in posttest invented spelling, word reading, letter knowledge, print concepts, and vocabulary knowledge captured by each predictor after controlling for the autoregressive effect of prior ability. The third panel in Table 3 (i.e., Step 2b) shows the proportion of variance in later ability explained when all other emergent literacy predictors were entered into the analysis simultaneously after the autoregressor.

For invented spelling, the emergent literacy measures of phonemic awareness, letter knowledge, print concepts, and general verbal ability (i.e., vocabulary knowledge) emerged as significant predictors of growth in this area of skill. We next determined whether relations between the pretested abilities and growth in invented spelling were redundant with each other. Phonemic awareness emerged as the only unique predictor of growth in invented spelling performance, uniquely capturing approximately 11% of the variance. Thus, for the WERP-1 group, phonemic awareness was a strong contributor to growth in spelling. These results, coupled with the fact that invented spelling predicted growth in both kinds of phonemic awareness, provides important evidence that relations between phonemic awareness and spelling are best characterized as bidirectional.

For word reading skills, phonemic awareness, invented spelling, print concepts, letter knowledge, and vocabulary emerged as significant predictors of growth while controlling for the autoregressor. Phonemic awareness emerged as the only unique predictor when these variables were simultaneously specified as causes of growth in word reading. These results do not negate the importance of other predictors, but merely indicate that phonemic awareness was the most powerful unique cause of reading growth.

For letter knowledge, only print concepts emerged as a reliable predictor of growth, while controlling for the autoregressor. These results are consistent with the idea that children who were initially given reading related opportunities and experiences needed to acquire print concept knowledge were in a better position for learning letter knowledge than those who were not provided these literacy experiences. For print concepts, only vocabulary knowledge emerged as a unique predictor of growth in this area while controlling for the autoregressor. For vocabulary knowledge, none of the pretested abilities predicted growth in this area while controlling for the autoregressor.

We also examined relations between pretested abilities and emergent literacy outcomes in control children (not shown in Table 3). For invented spelling, pretest levels of letter knowledge, print concepts, and phonemic awareness captured significant ($p < .05$ or less) variance in later invented spelling, $R^{2\prime}s = .15$, .11, and .23, respectively. When these three predictors and the autoregressor were included in a simultaneous regression equation, phonemic awareness emerged as the only unique predictor, capturing approximately 14% of the variance in later invented spelling ($p < .001$).

Beginning phonemic awareness uniquely contributed approximately 15% of the variance in later word reading for control children while accounting for the autoregressor, vocabulary knowledge, print concepts, letter knowledge, and invented spelling ($p < .01$). No other significant relations emerged between initial emergent literacy skills and control children's growth in word reading, letter knowledge, or print concepts.

### *Training time and growth in emergent literacy skills*

The third research question asked whether the time children actually used the WERP-1 could uniquely predict growth in emergent literacy skills. The second panel in Table 3 (i.e., Step 2a) shows the proportion of variance in later emergent literacy skills explained by total time using the WERP-1 after controlling for the autoregressor.

The fourth panel in Table 3 (i.e., Step 2c) shows the unique contributions of time using the WERP-1 while controlling for all of the initial emergent literacy skills (including the autoregressor). The amount of time that children used the WERP-1 uniquely contributed to performance in phonemic awareness, invented spelling, letter knowledge, and print concepts. These findings are especially important because they show that to some extent children can improve in phonemic awareness independently of the emergent literacy skills that they initially bring into the intervention experience. If initial reading-related abilities make a difference regardless of the amount of training children received, then these skills should explain variability in posttest emergent literacy skills while controlling for the time children used the WERP-1. This prediction was supported for all emergent literacy outcomes.

## Discussion

In this study, three questions were addressed regarding prediction of variability in responses to phonemic awareness training in disadvantaged kindergartners. We first describe the answers to the three questions addressed in this study and then mention some directions for future research.

### *Initial emergent literacy skills and growth in phonemic awareness*

The present results provide evidence of relations between individual differences in each kind of emergent literacy skill and growth in phonemic awareness in response to phonemic awareness instruction. Pretested levels of each kind of emergent literacy skill, except word reading, were associated with growth in phonemic awareness. When prior letter knowledge, invented spelling, vocabulary knowledge, print concepts, and the autoregressive effect of prior phonemic awareness were considered together in the same predictive equation, the influences of these factors were highly redundant with each other. Consistent with Torgesen and Davis (1996), we found that spelling emerged as the most powerful consistent predictor of growth in phonemic blending and segmenting skill.

The similar pattern of results between data sets is particularly interesting given the differences in training. Torgesen and Davis (1996) used teacher-led small group interactions as the primary vehicle for phonemic awareness instruction, while the current data set involved computer-assisted instruction. Our findings thus provide important evidence that factors contributing to children's responses to phonemic awareness instruction are invariant to the mode of training. The fact that both training methods can lead to substantial improvements in phonemic awareness has important educational value. Computer-assisted instruction requires much less teacher or aide time to deliver equivalent amounts of phonemic awareness instruction (Foster et al., 1994). Thus, computer-assisted instruction provides a cost effective way for school districts to provide consistently effective phonemic awareness instruction to at-risk children.

Group comparisons of performance on the posttest measures clearly revealed differences in phonemic awareness, but showed no differences in some other outcomes, including letter writing, name, or sound knowledge or print concepts. Obviously, children in the control group were provided sufficient instruction in letter knowledge and print concepts. The fact that control children improved in letter knowledge, and yet did not improve in phonemic awareness, provides important evidence that teaching children letter names and sounds alone is not sufficient for acquisition of phonemic awareness skills in children who live in poverty (cf. Ball & Blachman, 1991).

Yet, some children in the WERP-1 group did not respond to the phonemic awareness training. In the current data set, approximately 29% of the WERP-1 sample did not improve by more than 1 point on the phonemic segmenting task, and 10% did not improve by more than 2 points on the blending task. These figures are very similar to the percentage of the sample who were treatment resisters reported by Torgesen and Davis (1996). Specifically, they reported that between the pre- to posttest time periods, approximately 35% of their sample did not improve by more than 1 point on the phonemic segmenting task, and about 10% of their sample did not score more than 2 points on the blending task during the same time points. The corresponding figures for the current control children for phonemic segmenting and blending were approximately 74 and 42%, respectively. Obviously, an important area for future research is the development of procedures for enhancing the phonemic awareness skills of children who do not appear to show substantial growth during phonemic awareness instruction. These students arguably have a true learning disability that is not related to lack of exposure to a validated treatment protocol such as the WERP-1 (cf. Berninger & Abbott, 1994).

*Initial emergent literacy skills and growth in invented spelling, word reading, letter knowledge, print concepts, and vocabulary knowledge*

The second question addressed in this study asked whether children's initial emergent literacy skills could explain growth in the other emergent literacy outcomes in those exposed to phonemic awareness training. Perhaps the most interesting of these analyses concerned prediction of growth in invented spelling and reading. These outcomes were significantly enhanced by the WERP-1 when compared to controls.

Growth in invented spelling skills in response to phonemic awareness instruction was explained by pretest levels of letter knowledge, vocabulary knowledge, print concepts, and phonemic awareness. Interestingly, only phonemic awareness emerged as a unique predictor of growth in spelling skills, while controlling for the other emergent literacy predictors. These results are consistent with the idea that the influences of phonemic awareness and early invented spelling skills are bidirectional. That is, phonemic awareness substantially influenced growth in emergent spelling skills and vice versa. Interestingly, children in the control group also improved their invented spelling skills even though these children did not improve in phonemic awareness. Initial phonemic awareness was the most powerful pretest predictor of growth in invented spelling. Children in the control group had relatively little awareness and sensitivity to the sound structure of oral language; however, their level of skill was sufficient for enabling some growth in invented spelling. Unfortunately, beginning levels of invented spelling were not sufficient for enabling any growth in phonemic awareness in the control group.

Two plausible alternative explanations to the bidirectional view of relations between invented spelling and phonemic awareness in response to instruction deserve mention. As suggested by a reviewer, prediction of individual differences in pretest phonemic awareness and invented spelling performance at this age may reflect a common third variable. For example, a general learning-rate factor (Byrne, Fielding-Barnsley, & Ashley, 2000) may underlie relations between pretested invented spelling and phonemic awareness and posttest performance on these variables. Pretest phonemic awareness and invented spelling may simply be capturing additional reliable variance in the common third factor that influences both skills. Although our data cannot absolutely rule out this possibility, we note that the bidirectional pattern of findings were obtained while controlling for all other emergent literacy skills, including the autoregressor, which also ought to be influenced by a general learning rate factor. Invented spelling and phonemic awareness may basically measure the same underlying speech-processing skill. Thus, any reliable variance in later invented spelling or phonemic awareness not captured by the autoregressor will be captured by the other measure of ability. This possibility seems consistent with Mann et al.'s

(1987) hypothesis that invented spelling can be used as a proxy for phonemic awareness in kindergarteners.

Interestingly, although the current training program did not include explicit instruction in word level reading, we found a significant advantage in the WERP group for word reading than the controls. This finding is consistent with previous research suggesting improvements in word reading as a result of phonemic awareness training without explicit decoding instruction when compared to no-treatment control children (Fuchs et al., 2001; Tangel & Blachman, 1992).

### *Training time and growth in emergent literacy skills*

The third question asked whether the amount of time that children received phonemic awareness training uniquely influenced emergent literacy outcomes independently of initial reading-related skills and vice versa. The amount of time that children used the WERP-1 was correlated with all posttest measures of emergent literacy skills. Importantly, intervention time was uniquely associated with growth in phonemic awareness skills, even while controlling for initial levels of phonemic awareness, letter knowledge, invented spelling, vocabulary knowledge, and print concepts. Similarly, the amount of time using the WERP-1 was also uniquely related to growth in invented spelling, letter knowledge, and print concepts. Thus, the present results suggest that a new variable should be included in connection with any assessment of the effectiveness of a phonemic awareness intervention amount of time children were actually exposed to the treatment protocol.

Time using the WERP-1 intervention was positively correlated with most pretest measures. Apparently, children who start out poorer in reading-related skills may continue to have reading difficulties because they receive less exposure to the training that they need most (Stanovich, 1986). In fact, the "treatment resister" children in the current study, defined as those who did not improve by more than two correct items on either the blending or segmenting tasks, received approximately 10 h less WERP-1 instructional time than those who showed substantial improvement in phonemic analysis and blending skills, $t(40) = 6.004$, $p < .001$. Clearly, children with poorer literacy-related skills should be given more time using the treatment protocol. By ensuring equal exposure to validated treatment protocols, perhaps future studies can produce a reduction in the percentage of children who do not improve in phonemic awareness skills.

### *Directions for future research*

Three directions of future work seem most important. First, additional characteristics of children should be identified in order to explain more variability in posttest phonemic awareness and spelling skills. Reading-related experiences and opportunities that children receive should influence growth in phonemic awareness skills (Hecht et al., 2000; Shatil et al., 2000). For example, the quality of the home literacy environment (e.g., availability of books in the home and time spent reading with parents), parental involvement in their child's schooling, and achievement motivation may influence growth in phonemic awareness skills (e.g., Christenson, Hurley, Sheridan, & Fenstermacher, 1997; Knapp & Woolverton, 1995). A focus on process variables that influence children's phonemic awareness development will likely help to better differentiate which children from low-income backgrounds succeed or fail in reading-related skills such as phonemic awareness (Hecht & Greenfield, 2001).

A second important avenue for future research is to determine whether the current results generalize to younger children (e.g., preschoolers enrolled in HeadStart programs) and older children. Average training effects may reflect a "hothouse" effect from those children who would have learned how to read normally without the intervention (Torgesen & Davis, 1996). Thus, the WERP phonemic awareness training may have been most beneficial for children who would have acquired sufficient phonemic awareness skills anyway in first- or second-grade. Future research should therefore focus on how to improve the phonemic awareness skills of older children with reading-related difficulties, particularly those students who have not yet sufficiently responded to phonemic awareness training given in kindergarten.

A third area for future research is to determine the degree to which findings concerning predictors of growth in phonemic awareness skills in response to instruction applies to the improvement of current phonemic awareness training programs. The current results suggest that interventions designed to improve phonemic awareness should combine explicit training in the sound structure of oral language with considerable emphasis on early spelling skills. In addition, the current results support the idea that the amount of time actually exposed to phonemic awareness instruction should be given special attention in any effort to both improve the overall effectiveness of an intervention and reduce the occurrence of treatment resisters.

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