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What is This?
Factors That Influence Phoneme–Grapheme Correspondence Learning

Daria M. Mauer and Alan G. Kamhi

Abstract

The present study examined (a) the relative impact visual and phonetic factors have on learning phoneme–grapheme correspondences, and (b) the relationship between measures of visual and phonological processing and children's ability to learn novel phoneme–grapheme correspondence pairs. Participants were 20 children with reading disabilities (RD), 10 normally achieving children matched for mental age (MA), and 10 children matched for reading age (RA). The children ranged in age from 5 years 2 months to 9 years 3 months. All children completed a phoneme–grapheme learning task consisting of four novel correspondence pairs, a visual processing task, and five measures of phonological processing. The MA and RA groups learned the four correspondence pairs in significantly fewer trials than the RD group. The RD group had the least difficulty learning the correspondence pair with different phonemes and graphemes and the most difficulty learning the correspondence pair with similar phonemes and graphemes. Performance on the learning task was significantly correlated to performance on the visual processing task and the five measures of phonological processing. Performance on the phonological processing task of short-term memory was the best predictor of overall performance on the learning task. Although children with RD were able to learn the four novel correspondence pairs, their processing deficiencies affected how readily they learned each of the correspondence pairs.

There has been considerable evidence to suggest that the major difficulty confronting the beginning reader is developing rapid (automatic) word-recognition skills. Theorists (e.g., Chall, 1983; Ehri, 1991; Frith, 1985; Spear-Swerling & Sternberg, 1994) have suggested that the developmental path to rapid word recognition involves a number of stages. At the earliest stage, children rely on some visual cue, such as the word's shape, or they use a distinctive logo to recognize words (e.g., Coca Cola, McDonald's). At the next stage, children begin to apply knowledge of phoneme–grapheme correspondences to word recognition. At the beginning of this stage, children's use of this knowledge involves only the first or last letters in a word. For example, a child might recognize the word dog based primarily on the initial /d/. In the next stage, referred to as controlled word recognition (Spear-Swerling & Sternberg, 1994), children make use of all letters to decode words. Decoding at this stage still requires considerable effort. It is not until the next stage, automatic word recognition, that children's word-recognition skills are not only accurate but also effortless (Spear-Swerling & Sternberg, 1994). The importance of effortless, automatic word recognition in increasing comprehension has been noted by many researchers (e.g., LaBerge & Samuels, 1974; Perfetti, 1985; Stanovich, 1987). The automatization of word recognition allows children to devote the majority of their mental resources to understanding the text and acquiring new concepts and information (Spear-Swerling & Sternberg, 1994).

To decode words phonetically, children must have at least a rudimentary level of phonological awareness: They must realize that words consist of discrete sounds and that these sounds are the same ones that make up the stream of speech they use and hear. They also must realize that letters and sounds map onto each other in some systematic way. Learning the phoneme–grapheme correspondences necessary to begin to phonetically decode words involves at least three distinct skills: the ability to (a) recognize and distinguish between letters, (b) process phonological information, and (c) associate specific letters with specific sounds.

Children with reading disabilities (RD) may have difficulty in each of these areas. For example, a number of researchers have found that children with RD have difficulty distinguishing the subtle visual differences between letters (e.g., b/d, g/p) (Fletcher & Satz, 1979; Lovegrove, Bowling, Badcock, & Blackwood, 1980). Deficiencies in phonological awareness and other aspects of phonological process-
ing have been well documented in children with RD (Brady & Shankweiler, 1991; Shankweiler, Liberman, Mark, Fowler, & Fischer, 1979; Torgesen, Wagner, & Rashotte, 1994; Wagner & Torgesen, 1987). Children with RD have also been found to have difficulty constructing associations between phonemes and graphemes (Manis et al., 1987; Vellutino & Scanlon, 1982, 1991; Vellutino, Steger, & Kandel, 1972).

The present study is a logical extension of the series of studies conducted by Vellutino and his colleagues in the 1970s (see Vellutino & Scanlon, 1982, for a review). They compared the ability of good and poor readers to construct associations between verbal and nonverbal stimuli. The findings were straightforward and consistent across studies. Poor readers performed comparably to nondisabled readers in learning associations between visual and nonverbal stimuli (e.g., simple designs paired with nonverbal noises, such as a cough, a high hum, a smooch, etc.). In contrast, the poor readers performed worse than the good readers in learning associations involving a verbal component (e.g., pairing pictures or letter-like figures with consonant–vowel–consonant nonsense syllables). Based on these studies, Vellutino and colleagues concluded that poor readers, as a group, do not have a generalized or pervasive deficit in associative learning. The difficulty poor readers have constructing associations between visual and verbal information suggests a limitation that is specific to processing verbal stimuli.

The finding that poor readers do not have a generalized difficulty in associative learning is an important one. Still unclear, however, is the relative impact visual and phonetic factors have on learning phoneme–grapheme correspondences. In another series of studies, Vellutino and his colleagues (e.g., Vellutino, Smith, Steger, & Kaman, 1975; Vellutino et al., 1972) demonstrated that poor readers exhibit age-level performance in recalling, copying, and discriminating visual stimuli (e.g., words, numerals, geometric designs). The confusion average and good readers have with visually similar letters, such as b and d, is thought to reflect naming problems (Calfee, 1977), that is, a problem associating the visual and phonetic features associated with each letter with its name. It is unclear, however, whether children have difficulty learning certain associations because of the visual similarity of the letters, the phonetic similarity of the sounds, or a little of both. It is also unclear how visual and phonological processing abilities affect children’s ability to construct correspondences with visually and phonetically similar sounds.

To address these questions, we compared the number of trials that children with RD, children matched for mental age, and children matched for reading level needed to learn four novel phoneme–grapheme correspondence pairs with different combinations of phonetic and visual similarity. For example, one pair contained phonetically different phonemes (/m/, /s/) paired with visually different graphemes, whereas another pair contained phonetically similar phonemes paired with visually different graphemes. The two other pairs contained similar phonemes/graphemes and different phonemes/graphemes. Children were also administered a visual processing task and five measures of phonological processing. The five measures chosen tapped encoding, storage, and retrieval of phonological information, as well as phonological awareness. We questioned whether performance on these tasks was significantly related to performance on the phoneme–grapheme learning task.

Based on previous research, we anticipated that children with RD would perform comparably to both groups of nondisabled children on the visual processing task, but more poorly than the age-matched group on the measures of phonological processing and the novel phoneme–grapheme learning task. We also anticipated that all of the children would have the least difficulty learning the correspondence pair with phonetically different phonemes and visually different graphemes and the most difficulty learning the correspondence pair with phonetically similar phonemes and visually similar graphemes. The facility with which the children learned the two other associations would indicate the differential effects of visual and phonetic factors on constructing phoneme–grapheme correspondences.

Method

Participants

Participants were 40 elementary-school children (in kindergarten and first and second grade) ranging in age from 5 years 2 months to 9 years 3 months. The 40 children were divided into three groups: One consisted of 20 children, (13 boys and 7 girls) with reading disabilities (RD); the other two groups consisted of 10 normally achieving children per group (each had 6 boys and 4 girls) matched for either mental age (MA) or reading age (RA) to the children with reading disabilities. Seven of the children with RD were African American; there were four African American children in each of the normative groups. The remaining children were Caucasian.

The special educators were instructed to distribute permission forms to children on their caseload who were identified as reading disabled in the first and second grades. Twenty eligible children with RD were then randomly selected. Teachers of the various classrooms were instructed to give permission forms to those children who were developing age-appropriately in reading and had no previous history of speech–language difficulties. The normally achieving groups were then matched for mental age or reading age to the children with reading disabilities. The normally achieving children attended the same schools as the children with RD. Twelve of the children with RD and 12 normally developing
children attended public schools in a small city outside a major urban area; the remaining 16 children attended private schools in a major urban area. The public school typically attracted students from middle-class socioeconomic levels, whereas the private schools tended to attract students from upper-middle-class socioeconomic levels.

All children had normal vision and hearing, spoke English as a first language, and had no diagnosed gross neurological abnormalities, speech deficits, or severe emotional disturbance, as indicated by school records. To be included in the study, all children also had to perform within normal age limits on the Test of Nonverbal Intelligence (TONI; Brown, Sherbenou, & Johnsen, 1982) and the Letter Check-list subtest of the Woodcock Reading Mastery Test–Revised (WRMT-R; Woodcock, 1987). The children were asked to identify the initial sounds and letters of 16 monosyllabic words to ensure that they had the basic knowledge required to learn novel phoneme-correspondence pairs (see Appendix A). The three groups are described in more detail below. Table 1 presents group means and standard deviations for age and measures of cognitive, language, and reading performance.

**RD Group.** The 20 children with reading disabilities ranged in age from 6 years 9 months to 9 years 3 months ($M = 8$ years 2 months). These children had been previously classified by the school systems as learning disabled based on the following criteria: (a) average to above-average intelligence as measured by the Wechsler Intelligence Scale for Children–Revised (WISC-R); (b) a lag of at least 1 year in reading skills; and (c) no evidence of sociocultural deprivation, behavioral disturbances, or organic abnormalities. We were not given access to the specific scores from the psychological evaluation. On the Word Attack subtest of the WRMT-R, all of the children with RD performed within normal age limits on the TONI ($M = 95.5$), however, and performance on this test is highly correlated with performance on the WISC-R with 9-year-old children with LD ($r = .95$, as reported in the TONI test manual). On the Word Attack subtest of the WRMT-R, all of the children with reading disabilities obtained a score of 0; scores on the sound and letter identification task ranged from 14 to 16 (16 was the maximum score).

**MA Group.** The MA group consisted of 10 children ranging in age from 6 years 7 months to 8 years 3 months ($M = 7$ years 8 months). The TONI quotient and chronological age were used to determine mental age. The TONI quotients for the MA group ($M = 107.9$) were significantly higher than those of the RD group, $t(9) = 2.4$, $p < .05$. Although the mean mental age of the MA group was about 8 months higher than the mental age of the RD group, this difference was not significant, $t(9) = -.99$, $p > .10$. All of the MA children were reading at grade level, as indicated by their performance on the Word Attack and Word Identification subtests of the WRMT-R. All of the children obtained the maximum score of 16 on the sound and letter identification task.

**RA Group.** This group consisted of 10 children ranging in age from 5 years 1 month to 6 years 1 month ($M = 5$ years 5 months). These children were matched to the RD group

<table>
<thead>
<tr>
<th>Variable</th>
<th>Reading disabilities</th>
<th>Mental-age–matched</th>
<th>Reading-age–matched</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
<td>$M$</td>
</tr>
<tr>
<td>CA (months)</td>
<td>97.8</td>
<td>7.5</td>
<td>94.1</td>
</tr>
<tr>
<td>IQ</td>
<td>95.5</td>
<td>9.2</td>
<td>107.9</td>
</tr>
<tr>
<td>MA (months)</td>
<td>93.1</td>
<td>7.5</td>
<td>101.5</td>
</tr>
<tr>
<td>PVa</td>
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<td>17.2</td>
</tr>
<tr>
<td>Sia</td>
<td>8.0</td>
<td>3.2</td>
<td>17.4</td>
</tr>
<tr>
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<td>1.4</td>
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<td>3.4</td>
</tr>
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<td>WAb</td>
<td>0</td>
<td>0</td>
<td>2.9</td>
</tr>
<tr>
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<td>14.5</td>
<td>2.2</td>
<td>16</td>
</tr>
<tr>
<td>PGLc</td>
<td>14.8</td>
<td>1.3</td>
<td>16</td>
</tr>
</tbody>
</table>

Note. CA = chronological age; IQ = intelligence quotient; MA = mental age; PV = Picture Vocabulary (Test of Language Development–Preschool); SI = sentence imitation; WI = word identification; WA = word attack; PGS = phoneme–grapheme identification of sound; PGL = phoneme–grapheme identification of letter.

*aRaw scores. bGrade equivalent. cTotal possible = 16.*
based on their performance on the Word Attack and Word Identification subtests of the WRMT-R and the sound and letter identification task. None of the RA children could read any of the words on the Word Attack subtest and identified fewer than three words on the Word Identification subtest. On the sound and letter identification task, the children correctly identified 14 out of 16 sounds and 12 of 16 letters. The performance of the RA and RD children on these tasks was thus comparable.

**General Procedures**

Testing was completed in two sessions, each lasting approximately 1 hour. Each child was seen individually in a quiet room at school. The first author conducted all of the testing. During the first session, the Test of Language Development–Preschool (TOLD-P; Newcomer & Hammill, 1982), the TONI, the WRMT-R, and the sound and letter identification task were administered. The phoneme–grapheme learning task, the visual processing task, and the five measures of phonological processing (rapid naming of objects, rapid naming of letters/numbers/colors, short-term memory, sound categorization, and deletion) were administered in the second session. The order of presentation for the learning task, the visual task, and the phonological processing tasks was counterbalanced. The specific procedures for each of the tasks are described in detail below.

**Phoneme-Grapheme Learning Task**

The phoneme–grapheme learning task involved matching particular phonemes with novel letter-like symbols (i.e., novel graphemes). Initially, the students were taught four novel phoneme–grapheme correspondence pairs that consisted of (a) phonetically different phonemes (/m,s/ or /sh,n/) paired with visually different graphemes; (b) phonetically different phonemes (/b,d/ or /p,t/) paired with visually similar graphemes; (c) phonetically similar phonemes paired with visually different graphemes; and (d) phonetically similar phonemes paired with visually similar graphemes. Two different sets of the four correspondence pairs were randomly assigned to half of the children in the three groups. The specific phonemes and corresponding graphemes for the two sets of four correspondence pairs appear in Figure 1.

Students in each group were given up to 15 trials to learn each of the four different correspondence pairs. Each trial consisted of a training phrase and a probe phase. The training phase consisted of 10 pictures of objects beginning with the first targeted phoneme followed by 10 pictures beginning with the paired phoneme. As each picture was presented, the examiner told the child the first letter of the word while pointing to the corresponding grapheme. The letters trained were alternated, and the words were randomly presented. The order of presentation within each group of correspondence

**Group 1**

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>phonetically similar</td>
<td>phonetically different</td>
<td>phonetically different</td>
<td>phonetically similar</td>
</tr>
<tr>
<td>visually similar</td>
<td>visually different</td>
<td>visually similar</td>
<td>visually different</td>
</tr>
<tr>
<td>b</td>
<td>m</td>
<td>sh</td>
<td>p</td>
</tr>
<tr>
<td>d</td>
<td>s</td>
<td>n</td>
<td>t</td>
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</tbody>
</table>

**Group 2**

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<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>phonetically similar</td>
<td>phonetically different</td>
<td>phonetically similar</td>
<td>phonetically different</td>
</tr>
<tr>
<td>visually similar</td>
<td>visually different</td>
<td>visually similar</td>
<td>visually different</td>
</tr>
<tr>
<td>m</td>
<td>s</td>
<td>b</td>
<td>d</td>
</tr>
<tr>
<td>p</td>
<td>t</td>
<td>sh</td>
<td>n</td>
</tr>
</tbody>
</table>

**FIGURE 1.** The specific phonemes and corresponding graphemes for the two sets of four novel correspondence pairs.
pairs was counterbalanced. Right–left placement of the shapes was varied to ensure understanding of phoneme–grapheme correspondence rather than rote memory of location.

The probe phase consisted of 10 different pictures beginning with the previously trained phonemes (five of each phoneme). Children were asked to point to the “letter/shape” that corresponded to the first sound of the picture presented. Training continued until a child correctly identified 9 of the 10 probe items for two consecutive trials. Children received up to 15 trials to reach this criterion. All but 3 children with RD were able to learn the phoneme–grapheme correspondence rules within 15 trials. These 3 children were given a score of 15; all of the other children reached criterion before the 15th trial.

### Visual and Phonological Processing Tasks

The visual processing consisted of 12 items: 6 alphabetic–like symbols and 6 novel visual symbols similar to those used in the phoneme–grapheme learning task. Children were asked to match the target symbol with one of four choices that varied in spatial direction and form. Responses were scored as correct or incorrect. This task appears in Appendix B.

There were five measures of phonological processing: two measures of phonological awareness (sound deletion and sound categorization), two measures of rapid naming (letters/numbers/colors and common objects), and a measure of short-term memory. The instructions and items for each of these tasks appear in Appendix B. The tasks are described in more detail below.

### Sound Deletion

This task was based on procedures used by Rosner and Simon (1971). Previous studies have used primarily monosyllabic words with deletion of initial and/or final phonemes (Kamhi & Catts, 1986; Rosner & Simon, 1971). In the present study, children were asked to take away the initial syllables of 10 bisyllabic words and the initial phonemes of 10 monosyllabic words. Responses were scored as correct or incorrect.

### Sound Categorization

For this task, children were asked to select the word that did not contain the same beginning sound as the other two words. For example, given the words *much*, *night*, and *nine*, the correct response was *much* because it did not begin with an /n/. The words and procedures used were based on Bradley (1980). The 10 items were scored as correct or incorrect.

### Short-Term Memory

For this task, children were asked to repeat a series of three monosyllabic consonant–vowel–consonant (CVC) nonsense words (e.g., *var*, *dap*, *tif*) that were presented via a tape recorder. There were 10 items in the task. The words and procedures used were based on Kamhi, Catts, Mauer, Apel, and Gentry (1988). A score of 30 was possible (10 items of 3 words each). Responses were scored as correct if the major phonetic components of the word were produced in the correct sequence. Phoneme substitutions, omissions, additions, and deletions were scored as errors. Children were not penalized for articulatory distortions (e.g., lateralized /s/). Order of recall was not scored.

### Rapid Naming

Children completed two rapid naming tasks. The first task consisted of five letters (*a*, *d*, *o*, *s*, *p*), five numbers (*2*, *4*, *6*, *7*, *9*), and five colors (*red*, *blue*, *black*, *yellow*, *green*) repeated 10 times in a fixed A-B-C-A-B-C pattern totaling 50 items. The materials for the letters, numbers, and colors were similar to those used by Denckla and Rudel (1976) and Wolf (1984). The second task consisted of pictures of five common objects (key, comb, star, hand, ball) repeated 10 times in a fixed A-B-C-D-E-A-B-C-D-E pattern totaling 50 items. Children were first asked to name each of the items to ensure that this information was stored in long-term memory. Children were then instructed to name each item on the chart, left to right and row to row, as quickly and as accurately as possible. A stopwatch was used to measure the time taken by each subject to name the 50 items on each chart.

### Reliability

Intra- and interjudge reliability agreement was determined for the short-term memory, sound deletion, sound categorization, and two rapid naming tasks. Children’s responses on all of these tasks were recorded on a Marantz PMD 201 cassette recorder with a Sony dynamic microphone. Responses were immediately transcribed by the first author. Responses from 4 children in each group were rescoring within 1 week of the test session. Intra-judge agreement was 100%. A graduate student in speech–language pathology independently transcribed and scored data from a different set of 4 children from each group. Inter-judge reliability across the four tasks was 95.6% to 98.3%. Disagreements occurred on the two naming tasks; these disagreements were resolved by having both judges time the responses together.

### Results

No significant differences existed between the two sets of stimuli used in the phoneme–grapheme learning task, $F(1, 68) = .84, p > .10$; thus, subsequent analyses involving the stimuli were collapsed.

### Phonetic and Visual Similarities

The first analysis compared each group’s performance (number of trials to reach criterion) in learning the four correspondence pairs (see Table 2). Because there was a significant difference in the TONI quotients (IQ)
between the RD and RA groups, IQ was treated as a covariate in the analysis of group differences. A 3 (Group) x 4 (Correspondence Pair) MANCOVA indicated that there was a significant difference among group means across the four correspondence pairs, $F^2(2, 64) = 4.23, p < .001$. IQ did not contribute significantly to performance on the learning task. Scheffé post hoc procedures ($p < .01$) indicated that the MA and RA groups learned the four correspondence pairs in significantly fewer trials than the RD group. As can be seen in Table 2, both groups of nondisabled children needed two or three trials to learn all four of the correspondence pairs. Recall that acquisition was defined as two consecutive trials in which the child correctly identified 90% (9 out of 10) of the probe items. The number of trials required to reach acquisition was remarkably similar for both nondisabled groups across the four correspondence pairs; most of these children acquired all of the pairs in the minimum number of trials. In fact, across the two groups, all but the one correspondence pair (similar phoneme and grapheme for the RA group) were acquired in two or three trials.

In contrast to the two nondisabled groups, the children with RD performed differently across the four correspondence pairs. They had the least difficulty learning the correspondence pair with different phonemes and graphemes, and the most difficulty learning the correspondence pair with the similar phonemes and graphemes. Scheffé post hoc procedures ($p < .05$) indicated that significant differences existed between (a) the pairs with similar phonemes and graphemes and the pairs with different phonemes and graphemes, (b) the pairs with similar phonemes and graphemes and the pairs with different phonemes and similar graphemes, and (c) the pairs with different phonemes and graphemes and the pairs with different phonemes and similar graphemes. No differences were found in the learning rate between the pairs with similar phonemes/different graphemes and different phonemes/similar graphemes.

Although no significant difference was found in learning rates between the pairs with similar phonemes/different graphemes and different phonemes/similar graphemes, the significant differences noted in (b) and (c) above indicate that visual similarities caused slightly more problems than phonetic similarities. The .6 difference ($6.2 - 5.6 = .6$) in the mean number of learning trials between the two mixed correspondence pairs was enough to make the (b) and (c) comparisons significant. The children with RD needed slightly more than 2.5 trials ($8.4 - 6.2 = 2.2; 5.6 - 3.6 = 2$) to learn correspondences with visual similarities, compared to about two trials.

### Table 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Reading disabilities</th>
<th>Mental-age-matched</th>
<th>Reading-age-matched</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
<td>$M$</td>
</tr>
<tr>
<td>Similar phoneme/ similar grapheme</td>
<td>8.4</td>
<td>3.3</td>
<td>2.5</td>
</tr>
<tr>
<td>Similar phoneme/ different grapheme</td>
<td>5.6</td>
<td>2.7</td>
<td>2.0</td>
</tr>
<tr>
<td>Different phoneme/ similar grapheme</td>
<td>6.2</td>
<td>2.2</td>
<td>2.0</td>
</tr>
<tr>
<td>Different phoneme/ different grapheme</td>
<td>3.6</td>
<td>1.6</td>
<td>2.0</td>
</tr>
</tbody>
</table>

**Visual and Phonological Processing Tasks**

Table 3 presents the data for the visual processing task and the five phonological processing tasks. TONI quotients were again treated as a covariate. A 3 (Group) x 6 (Tasks) MANCOVA indicated a significant difference among the means for the six tasks, $F^2(12, 60) = 6.67, p < .001$. IQ did not contribute significantly to performance on these tasks. Scheffé post hoc analyses ($p < .01$) indicated that the RD group performed significantly worse than the MA group on all six tasks. The RD group also performed significantly worse than the RA group on the visual processing task, the short-term memory task, and the rapid naming of objects. Although the MA group consistently performed better than the younger RA group across the five tasks, a significant difference was found only on the short-term memory task and rapid naming of letters/numbers/colors.

### Correlational and Regression Analyses

Table 4 presents the correlation of coefficients between the various processing measures and performance on
TABLE 3
Group Performance on Visual and Phonological Processing Tasks

<table>
<thead>
<tr>
<th>Task</th>
<th>Reading disabilities</th>
<th>Mental-age-matched</th>
<th>Reading-age-matched</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M  SD</td>
<td>M  SD</td>
<td>M  SD</td>
</tr>
<tr>
<td>Visual discrimination (Total possible = 12)</td>
<td>9.5 1.9</td>
<td>11.9 .3</td>
<td>11.4 .8</td>
</tr>
<tr>
<td>Short-term memory (Total possible = 30)</td>
<td>10.0 3.7</td>
<td>20.9 2.9</td>
<td>17.2 3.3</td>
</tr>
<tr>
<td>Sound deletion (Total possible = 20)</td>
<td>11.4 5.8</td>
<td>17.6 3.2</td>
<td>14.1 4.8</td>
</tr>
<tr>
<td>Sound categorization (Total possible = 10)</td>
<td>5.0 2.7</td>
<td>9.0 1.7</td>
<td>7.2 2.6</td>
</tr>
<tr>
<td>Rapid naming of objects (in seconds)</td>
<td>70.1 17.3</td>
<td>49.9 5.8</td>
<td>55.4 6.1</td>
</tr>
<tr>
<td>Rapid naming of letters/numbers/colors (in seconds)</td>
<td>67.0 17.3</td>
<td>37.6 4.8</td>
<td>55.7 6.1</td>
</tr>
</tbody>
</table>

the four correspondence pairs. As can be seen in this table, all but two of the coefficients were significant. Coefficients tended to be lower for the different phoneme/different grapheme pair. Separate step-wise regression analyses were conducted to determine which of the processing variables predicted performance on each of the correspondence pairs. Performance on the short-term memory task accounted for 47% of the variance for the similar phoneme/similar grapheme pair and 30% of the variance for the similar phoneme/different grapheme pair. Sound categorization accounted for an additional 12% of the variance for the similar phoneme/similar grapheme pair. Performance on the visual processing task accounted for 39% of the variance for the different phoneme/similar grapheme pair. Sound categorization accounted for an additional 11% of the variance. Rapid naming of letters/numbers/colors accounted for 20% of the variance for the different phoneme/different grapheme pair. Performance on the visual processing task accounted for an additional 9% of the variance.

Correlation coefficients were also calculated between a composite measure of performance on the learning task and the five measures of phonological processing and the measure of visual processing. The composite measure consisted of the total number of trials to acquisition across the four learning tasks for each child. As can be seen in Table 4, the coefficients ranged from .41 on the rapid naming of letters/numbers/colors task to .67 on the short-term memory task. A multiple step-wise regression analysis confirmed that performance on the

TABLE 4
Pearson Product-Moment Correlation Coefficients Between the Learning Task and Processing Tasks

<table>
<thead>
<tr>
<th>Task</th>
<th>Similar phoneme/ similar grapheme</th>
<th>Similar phoneme/ different grapheme</th>
<th>Different phoneme/ similar grapheme</th>
<th>Different phoneme/ different grapheme</th>
<th>Total score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual processing</td>
<td>.63***</td>
<td>.51**</td>
<td>.62***</td>
<td>.39*</td>
<td>.64***</td>
</tr>
<tr>
<td>Short-term memory</td>
<td>.68***</td>
<td>.55***</td>
<td>.62***</td>
<td>.45**</td>
<td>.68***</td>
</tr>
<tr>
<td>Sound deletion</td>
<td>.50**</td>
<td>.35*</td>
<td>.46**</td>
<td>.31</td>
<td>.48**</td>
</tr>
<tr>
<td>Sound categorization</td>
<td>.67***</td>
<td>.52**</td>
<td>.59***</td>
<td>.37*</td>
<td>.64***</td>
</tr>
<tr>
<td>Rapid naming of objects</td>
<td>.52**</td>
<td>.52**</td>
<td>.43**</td>
<td>.43**</td>
<td>.55***</td>
</tr>
<tr>
<td>Rapid naming of letters/ numbers/colors</td>
<td>.41**</td>
<td>.29</td>
<td>.37*</td>
<td>.45**</td>
<td>.42**</td>
</tr>
</tbody>
</table>

*p < .05. **p < .01. ***p < .001.
short-term memory task was the best predictor of performance on the learning task, accounting for 46% of the variance. Performance on the sound categorization task also contributed significantly to performance on the learning task, accounting for an additional 10% of the variance ($R^2 = 56\%$).

Discussion

The principal purpose of the present study was to examine the effects that variations in phonetic and visual factors had on the learning of novel phoneme–grapheme correspondences in children with reading disabilities. The RD group needed significantly more trials to learn the four correspondence pairs than either the MA or the RA group. The differences between the RD and MA groups were not surprising. Previous studies have found that children with RD have more difficulty than age-matched peers in forming auditory–visual associations (Done & Miles, 1978; Gascon & Goodglass, 1978; Vellutino, Harding, Phillips, & Steger, 1975; Vellutino et al., 1972). The differences between the RD and RA groups were more noteworthy. Despite the fact that the two groups were reading at the same level, the children with RD needed an average of three more trials to learn the four correspondence pairs.

Differences in the similarity of the phoneme and grapheme pairs had no effect on how quickly the two non-disabled groups learned the correspondence pairs. Children in these groups learned each of the correspondence pairs in about two trials—the minimum possible. A more difficult learning task may have uncovered differences in the non-disabled groups. The learning task proved sufficiently difficult for the RD group; the similarity of the phoneme and grapheme pairs significantly affected the number of trials it took the RD group to learn the correspondence pairs. Children with RD needed twice as many trials to learn the pairs containing similar phonemes and graphemes as they did to learn the pairs containing different phonemes and graphemes. Salient differences between phonemes and graphemes clearly made it easier for the RD group to construct correspondence pairs. Even though children with RD found this correspondence pair easier to learn than the other pairs, the nondisabled children in both groups needed even fewer trials than the RD group to learn this correspondence pair.

Of particular interest in this study was whether phonetic or visual confusions had more of an adverse effect on children’s learning of novel correspondence pairs. Children’s performance on the correspondence pairs with similar phonemes/different graphemes and different phonemes/similar graphemes addressed this question. No significant difference existed in learning rate between these two pairs for any of the groups. Although no significant differences between these pairs were found, visual confusions appeared to cause slightly more problems than did phonetic confusions for children with RD. The small difference in the mean number of learning trials between these two pairs (.6) was enough to make two of the other pair-wise comparisons significant. One should probably not make too much of this slight difference, however, unless future studies indicate that it is not a spurious finding.

Contribution of Visual Processing Skills

The measure of visual processing offers another way to assess the contribution of visual processing skills. The nondisabled groups made almost no errors on this task, whereas the RD group averaged 79% correct responses (see Table 3). Despite the relatively high performance levels of the RD group on this task, performance on this task was significantly correlated to overall performance on the learning task ($r = .63$). Consistent with what one would expect, visual processing abilities were highly correlated with performance on the two correspondence pairs containing similar graphemes ($r = .41/ .43$). The regression analysis confirmed that performance on the visual processing task accounted for 39% of the variance for the different phoneme/similar grapheme pair. These findings suggest that visual processing abilities have an impact on how readily children learn phoneme–grapheme correspondence pairs that contain visually similar graphemes. It is important to note that the extent of the impact may have been limited by the ceiling effects in the visual processing task. However, the items on the task were chosen because they were similar to the novel phonemes being learned. A more discriminating task may tap visual processing skills that are not related to differentiating between graphemes.

Role of Associative Learning and Reading Level

The children with RD clearly did not have a pervasive deficit in associative learning. Their ability to learn the four correspondence pairs, especially the different phoneme/different grapheme pair, indicates that they could readily construct associations between sounds and letters. The data in the present study are thus consistent with Vellutino and Scanlon’s (1982) claim that poor readers do not have a pervasive deficit in associative learning.

Reading level also seemed to have little impact on children’s performance on the learning task. If the present study had included only the RD and MA groups, reading level would have appeared to be related to performance on the learning task. However, the significant difference in performance on the learning task between the RD and RA groups indicates that word attack and word identification skills were not related to the ability to learn novel phoneme–grapheme correspondences. The RD and RA children were matched for word attack and word identification ability.
Impact of Phonological Processing Abilities

Phonological processing abilities clearly had a significant impact on how quickly children learned the four novel correspondence pairs. The children with RD performed more poorly than the MA group on all five measures of phonological processing, and more poorly than the RA group on two of the five measures: short-term memory and rapid naming of objects. The relatively poor performance of the RD group on the phonological processing tasks is consistent with previous studies that have documented phonological processing deficiencies in children with RD (Brady & Shankweiler, 1991; Torgesen, 1993; Torgesen et al., 1994). Not surprisingly, the five measures of phonological processing were all significantly correlated to performance on the learning task. Performance on the short-term memory and sound categorization tasks accounted for more than half of the variance (56%) on the learning task. The short-term memory task was the best predictor of performance on the two correspondence pairs that contained similar phonemes. This task measures the ability to construct accurate representations of phonological information. Constructing accurate representations of similar phonemes clearly places some demands on phonological memory (encoding) processes. The difficulty that children with RD had in learning these correspondence pairs thus can be directly attributed to their inefficient phonological memory processes.

Phonological awareness also contributed to performance on the learning task. The sound categorization task accounted for an additional 10% of the variance in learning all of the pairs and made specific contributions to the pairs involving similar phonemes/similar graphemes and different phonemes/similar graphemes. The present study was not designed to determine whether learning phoneme-grapheme correspondences requires a particular performance level on measures of phonological awareness or specific awareness of the phonemes being learned. Children in the RD group responded correctly to slightly more than half of the items on the two phonological awareness tasks, compared to about 70% of the items for the children in the RA group and 90% for children in the MA group. These data suggest that relatively low performance levels (e.g., 25% to 40%) on measures of phonological awareness may be sufficient for learning phoneme-grapheme correspondences, or that somewhat higher performance levels (55% to 70%) may be necessary for rapid learning to occur. The ability of the RA group to learn the four correspondence pairs as quickly as the MA group indicates that very high levels of performance (90%) on phonological awareness tasks were not required to learn the correspondence pairs quickly. Although performance on the sound categorization task did contribute some unique variance to children’s performance on the learning task, basic processing abilities (visual and phonological) seemed to have more of an impact on how readily children learned the four novel phoneme-grapheme correspondences. Future studies need to examine the specific contribution that phonological awareness makes to children’s ability to learn various phoneme-grapheme correspondences.

Rapid naming ability contributed less than the other phonological processing measures to performance on the learning task. Although performance on the two rapid naming tasks was significantly correlated to performance on the learning task, in only one case did one of these tasks account for a significant portion of the variance on the learning task. Rapid naming of letters/numbers/colors accounted for 20% of the variance for the different phoneme/different grapheme pair. This correspondence pair placed the least demands on visual processing and phonological memory abilities. The ability to readily access information from long-term memory may play more of a role in learning when other processing demands are reduced.

In summary, children with RD needed significantly more trials than nondisabled peers matched for MA and RA to learn four novel phoneme-grapheme correspondence pairs. The RD group needed twice as many trials to learn correspondence pairs containing similar phonemes and graphemes as they did to learn the pairs containing different phonemes and graphemes. Performance on the short-term memory task was the best predictor of overall performance on the learning task. Although children with RD were able to learn the four novel correspondence pairs, their processing deficiencies affected how readily they learned each of the correspondence pairs.

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AUTHORS’ NOTE

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REFERENCES


APPENDIX A
Phoneme–Grapheme Identification Task

INSTRUCTIONS: Each word was given orally by the experimenter and the student was asked to identify the initial alphabetic sound and letter of the word. For example, the student was asked, “What sound does bale start with?” and, after a response, was asked “What letter does bale start with?”

PRACTICE ITEMS: student’s first and last names

SAMPLE TEST ITEMS:
1. bale
2. teak
3. peer
4. sage
5. deer
6. neat
7. shale
8. mar
9. nag
10. pike

APPENDIX B
Visual and Phonological Processing Tasks

Visual Processing

INSTRUCTIONS: The student was asked to look at the symbol in the target box and then look carefully at the four choices and point to the symbol that was exactly the same as the one in the target box. Three practice items with corrective feedback were given, followed by the 12 test items.

TEST ITEMS:

Target symbol | Choices
---|---
![Symbol](image1) | ![Symbol](image2) ![Symbol](image3) ![Symbol](image4) ![Symbol](image5)

Rapid Naming Tasks

INSTRUCTIONS: In both tasks the student was instructed to name each item on the chart, left to right and row to row, as quickly and as accurately as possible. A stopwatch was used to measure the time taken by each student to name the items on the charts.

Letters/Numbers/Colors

<p>| | | | | | | | | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
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<td>red</td>
<td>p</td>
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<td>blue</td>
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<td>green</td>
<td>s</td>
<td>4</td>
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</tbody>
</table>

Objects

<p>| | | | | | | |</p>
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<th></th>
<th></th>
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</thead>
<tbody>
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<td>nose</td>
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<td>doll</td>
<td>nose</td>
<td>sock</td>
<td>nose</td>
<td>bike</td>
<td>comb</td>
</tr>
</tbody>
</table>
Short-Term Memory Task
INSTRUCTIONS: The student was instructed to listen carefully to the three words and say the words exactly as they were said.

PRACTICE ITEMS: bod bot

SAMPLE TEST ITEMS:
1. tab gul fiv
2. kir vang naz
3. sar zang dok
4. vag lom nis
5. zel bod rup

Sound Categorization Task
INSTRUCTIONS: “We are going to play a sound game. I am going to say three words. Two of the words begin with the same sound, and one word begins with a different sound. I want you to listen very carefully to the beginning of the words and tell me which of the words begins with a different sound—which one does not belong with the others. Wait until I have said all the words before you tell me which one it was. Listen.”

SAMPLE PRACTICE ITEMS: candy candle pocket

SAMPLE TEST ITEMS:
1. much night nine
2. feet song feed
3. safe same shirt
4. back day bad
5. cake ten tell

Sound Deletion Task
INSTRUCTIONS: The student was given a one- or two-syllable word and asked to say the word without the initial syllable or phoneme. There were three practice trials with corrective feedback, followed by 20 test items. In the training session, the student was shown a picture of a cow and a boy’s head and asked to say “cowboy.” The experimenter then covered the picture of the cow and asked the child to say what was left.

PRACTICE ITEMS: cowboy toothbrush cupcake

SAMPLE TEST ITEMS:
1. sunday
2. around
3. baby
4. selfish
5. door