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Teaching children with dyslexia to spell in a reading-writers' workshop

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Abstract To identify effective treatment for both the spelling and word decoding problems in dyslexia, 24 students with dyslexia in grades 4 to 9 were randomly assigned to treatments A (n=12) or B (n=12) in an after-school reading-writers' workshop at the university (thirty 1-h sessions twice a week over 5 months). First, both groups received step 1 treatment of grapheme–phoneme correspondences (gpc) for oral reading. At step 2, treatment A received gpc training for both oral reading and spelling, and treatment B received gpc training for oral reading and phonological awareness. At step 3, treatment A received orthographic spelling strategy and rapid accelerated reading program (RAP) training, and treatment B continued step 2 training. At step 4, treatment A received morphological strategies and RAP training, and treatment B received orthographic spelling strategy training. Each treatment also had the same integrated reading–writing activities, which many school assignments require. Both groups improved significantly in automatic letter writing, spelling real words, compositional fluency, and oral reading (decoding) rate. Treatment A significantly outperformed treatment B in decoding rate after step 3 orthographic training, which in turn uniquely predicted spelling real words. Letter processing rate increased during step 3 RAP training

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and correlated significantly with two silent reading fluency measures. Adding orthographic strategies with "working memory in mind" to phonics helps students with dyslexia spell and read English words.

Keywords Integrated reading-writing instruction · Morphological awareness instruction for dyslexia · Orthographic strategies instruction for dyslexia · Phonological decoding instruction for dyslexia · Rapid accelerated program for reading fluency

Numerous studies have shown that spelling disability tends to be the persisting problem in dyslexia across development. Developmental research supports this conclusion for *English* (Berninger, Nielsen, Abbott, Wijsman, & Raskind, 2008a; Bruck, 1993; Connelly, Campbell, MacLean, & Barnes, 2006; Lefly & Pennington, 1991; Maughan, Messer, Collishaw, Snowling, Yule, & Rutter, 2009), *Spanish* (Serrano & Defior, 2011), and *German* (Roeske, Ludwig, Neuhoff, Becker, Bartling, Bruder et al., 2009). English is a morphophonemic orthography (Nunes & Bryant, 2006; Venezky, 1970, 1999), which means that learning to spell and read words depends on learning how phonology (sound units like phonemes in spoken words), orthography (spelling units like one- and two-letter graphemes in written words), and morphology (word parts that signal meaning and grammar) are interrelated. Spanish and Italian have a more transparent orthography, which means that the relationships between phonemes and graphemes are constant, unlike English which has alternations (options), but morphology also contributes to word reading and spelling in transparent orthographies (see Arfé, De Bernardi, Pasini, & Poeta, 2011).

Research has documented a genetic basis for the spelling problems in developmental dyslexia (Byrne, Coventry, Olson, Hulslander, Wadsworth, DeFries et al., 2008; Olson et al., this special issue; Raskind, Hsu, Thomson, Berninger, & Wijsman, 2000; Roeske et al., 2009; Rubenstein, Matsushita, Berninger, Raskind, & Wijsman, 2011; Wijsman, Peterson, Leutenegger, Thomson, Goddard, Hsu et al., 2000). Likewise, brain imaging research has identified brain differences between children with and without dyslexia in (a) brain neuroanatomical structures correlated with spelling or spelling-related processes (e.g., Eckert, Leonard, Richards, Aylward, Thomson, & Berninger, 2003) and (b) functional brain activation when performing spelling or spelling-related language tasks (e.g., Richards, Berninger, Nagy, Parsons, Field, & Richards, 2005; Richards, Aylward, Berninger, Field, Parsons, Richards et al., 2006) or working memory tasks (e.g., Richards, Berninger, Winn, Stock, Wagner, Muse et al., 2007; Richards, Berninger, Winn, Swanson, Stock, Liang et al., 2009c). Given this biological basis for the spelling problems in dyslexia, children with dyslexia may require specialized spelling instruction.

However, parents often report that it is difficult to convince schools to provide services in spelling and writing for their children with dyslexia, especially after their reading skills improve (Berninger, 2006, 2008). That may be because relatively little is known about effective specialized writing instruction for children with dyslexia. That is why the current instructional study was conducted to begin to address what such instruction might include. Considering the bidirectional relationships between spelling and reading (e.g., Mehta, Foorman, Branum-Martin, & Taylor 2005), effective instruction might teach the alphabetic principle in both the reading direction (each child says the phoneme that corresponds to a grapheme) and in the spelling direction (each child writes the grapheme that corresponds to a heard phoneme). In English, these correspondences are not exactly the same in each direction (Venezky, 1970, 1999). Spelling problems can interfere with written composition in children with dyslexia (Berninger et al., 2008a), and completion of school assignments often requires the ability to integrate reading (e.g., source material) and writing (e.g., answering comprehension questions or composing a report). Thus, specialized writing instruction for children with dyslexia will also need to focus on composing and integrating reading and writing.

Specialized writing instruction for children with dyslexia should also keep working memory in mind because of considerable research evidence that reading and writing disabilities are associated with impairments in working memory (e.g., Berninger, Abbott, Thomson, Wagner, Swanson, Wijsman et al., 2006a; Berninger, Abbott, Nagy, & Carlisle, 2010; Desmond, Gabrieli, Wagner, Ginier, & Glover, 1997; Richards et al., 2009c; Swanson, 1999; Swanson & Siegel, 2001). For example, the phonological loop of working memory (Heilman, Voeller, & Alexander 1996; Richards et al., 2007) often operates more slowly in children with dyslexia (Amtmann, Abbott, & Berninger 2007). This difficulty may be assessed with a rapid automatic naming (RAN) task (e.g., individual names each letter in order in four rows of letters). The executive functions for supervisory attention in working memory may also be impaired and can be assessed with a rapid automatic switching (RAS) task (e.g., individual names alternating letters and numerals in four rows of letters; Wolf, 1986).

The invisible disability in dyslexia—difficulty in engaging working memory via the phonological loop in initiating language tasks, or in sustaining language processing, or in switching between language tasks—may be assessed with RAN and RAS tasks to make them visible for others to understand. For example, total time on RAN (naming letters) reflects the speed of phonological loop function, and change in time across rows on RAN reflects the ability to sustain phonological loop function. RAS, in contrast, reflects an executive function for self-regulating switching attention; total time on RAS (naming alternating letters and numbers) reflects the speed of switching attention, while change in time across rows on RAS reflects sustaining switching attention over time (Amtmann et al., 2007). Indeed, such RAN and RAS difficulties were observed in the response of the lowest achieving second grade spellers in response to specialized spelling instruction (Amtmann, Abbott, & Berninger, 2008). Thus, our specialized writing instruction teaches explicit strategies for self-regulating working memory components (phonological loop and supervisory attention). For example, children look at and point to one-letter or two-letter groups, say names of pictured words with target phonemes, and then say the target phoneme that corresponds with the letter or letter group. Teachers model and students imitate using this three-part strategy in rapidly alternating turns (Berninger, 1998).

Also, we make sure children attend to teachers saying words and sounds and then write the corresponding letters, that is, engage the orthographic loop of working memory (Berninger, Winn, Stock, Abbott, Eschen, Lin et al., 2008d). The fMRI study of Crosson, Rao, Woodley, Rosen, Bobholz, Mayer et al. (1999) showed that working memory stores and processes orthographic codes (written words and their parts) as well as phonological codes (spoken words and their parts). Evidence is accumulating for a link between the internal orthographic codes (e.g., letter forms) and sequential finger movements. This link between coded letter forms in memory with producing them by hand is the orthographic loop, which can be assessed with rapid automatic legible letter writing on the alphabet writing task (e.g., Berninger, Abbott, Augsburger, & Garcia, 2009; Berninger, Fayol, & Alamargot, in press a; Berninger et al., 2008a; Richards, Berninger, & Fayol, 2009a; Richards, Berninger, Stock, Altemeier, Trivedi, & Maravilla, 2009b; Richards, Berninger, & Fayol, in press). The orthographic loop supports (a) initiating, sustaining, and switching attention during letter access, retrieval, and production during handwriting, spelling, and composing and (b) integrating sounds with spelling units in learning to spell.

Phonological treatment may fix the phonological core deficit, but not working memory problems in dyslexia. Phonological awareness (thinking about sounds in spoken words) is not the same as the phonological loop (coordinating phonological and orthographic units during naming of letters or written words, that is, cross-code coordination). Training phonological loop via oral reading may benefit reading, but spelling may also need orthographic loop training. After participation in a writer's workshop in which students with dyslexia were taught to coordinate phonological loop and orthographic loop (Berninger et al., 2008d, study 1), functional temporal connectivity from brain regions involved in working memory to brain regions involved in phonological decoding (reading) and encoding (spelling) normalized (Richards & Berninger, 2008). Timing is critical in the cross-code integration process because each code has its own time course. Normal readers achieve the integration across narrow time gaps between aural/phonological and visual/orthographic codes (Breznitz, 2001, 2006), but those with dyslexia have wider time gaps to negotiate due to their slower orthographic processing, which interferes with cross-code integration (Breznitz, 2001, 2006, 2008; Breznitz & Misra, 2003). Some individuals with dyslexia struggle with decoding written words accurately (and also decode slowly), whereas others can decode accurately but not automatically—fast and without effort (Lovett, 1987). Thus, the current instructional study was designed to evaluate whether treatment might improve the accuracy and automaticity of both spelling and word decoding.

Also because English is a morphophonemic language, as explained in the introduction, learning to read and spell requires learning the interrelationships among the phonological codes in spoken words, orthographic codes in written words, and morphological codes in spoken and written words (e.g., Berninger, Raskind, Richards, Abbott, & Stock, 2008c; Richards et al., 2005). Effective instruction for dyslexia probably requires teaching in a way that coordinates the phonological, orthographic, and morphological relationships (Henry, 1989, 2003; Henry and Redding, 1996). Garcia, Abbott, and Berninger (2010) identified differences in phonological, orthographic, and morphological awareness in poor, average, and good spellers in grades 1 to 7; and at-risk second and fourth grade writers benefited from phonological, orthographic, and morphological awareness activities for spelling (Berninger, Vaughan, Abbott, Begay, Byrd, Curtin et al., 2002; Berninger, Rutberg, Abbott, Garcia, Anderson-Youngstrom, Brooks et al., 2006b).

Finally, research shows that two learning mechanisms contribute to learning to spell and decode: self-teaching and silent orthography. Children self-teach knowledge of orthography through phonological decoding (Share, 2004, 2008), which engages the phonological loop for cross-code integration of graphemes and phonemes; but children with dyslexia may require more other-supported explicit instruction in this integration process because of their difficulties in self-regulating supervisory attention in working memory, as discussed earlier. In addition, through abstraction of orthographic and morphological regularities, children also learn "silent orthography," that is, word-specific spelling in which not all letters correspond to phonemes (e.g., Berninger et al., in press a; Fayol, Hupet, & Largy, 1999a; Fayol, Thévenin, Jarousse, & Totereau, 1999b; Fayol, Largy, & Lemaire, 1994; Fayol, Totereau, & Barrouillet, 2006; Olson, Forsberg, & Wise, 1994a; Olson, Forsberg, Wise, & Rack 1994b; Olson, Datta, Gayan, & DeFries, 1999; Pacton, Perruchet, Fayol, & Cleeremans, 2001; Pacton, Fayol, & Perruchet, 2005). They also learn that some morphological units have predictable phonological relationships (pronunciation) when grapheme–phoneme correspondences (gpc) in alphabetic principle do not (e.g., *tion* or *sion* for suffixes marking a noun and -ous, -eous, -able, or –ible suffixes marking an adjective; Nunes & Bryant, 2006).

Again, because of their *invisible disability* in working memory, children with dyslexia may not abstract orthographic or morphological regularities in written words as easily as children without dyslexia. Little research has focused on what explicit teaching strategies may help them do so, but in our prior research, two teaching strategies—the Photographic Leprechaun and the Proofreaders' Trick strategies—helped students with dyslexia improve their supervisory attention to letter positions and letter sequences in written spellings (Berninger et al., 2008d, study 1; Richards et al., 2006). For the first strategy, children completed these ordered procedures for each target word on a list of words for the lesson: (a) named each letter in a target word, (b) made a mental photograph of the written word, (c) closed their eyes and visualized the written word in the mind's eye, (d) answered questions about the position of letter(s) in a word (e.g., third letter or last two letters in word), and (e) opened their eyes and checked their answer against the target word. For the second strategy, after carefully looking again at the target word, they closed their eyes, visualized it in their mind's eye, and spelled the word backwards. Finally, the steps of each strategy were repeated with the next target word on the list.

Experimental studies in schools showed that spelling problems in low-achieving spellers were responsive to intervention. Whole classrooms in multiple schools and school systems were screened to find the lowest achieving second grade spellers who were randomly assigned to alternative treatments for explicit instruction in applying correspondences between different units of spoken and written words to spelling high-frequency monosyllabic words or to a contact control (phonological awareness training with spoken words). The treatment groups were taught automatic gpc and transfer of these to spelling words. All groups composed on provided topics. Combining two strategies for making connections between spoken and written words—saying and looking at onset and rime units in syllables plus naming the word and then each letter in a word—resulted in the largest gains in spelling transfer words (same phoneme–grapheme relationships in different word contexts); but phoneme–grapheme strategies resulted in the fewest spelling errors during composing (Berninger, Vaughan, Abbott, Brooks, Abbott, Reed et al., 1998), thus demonstrating the value of multiple strategies. After 24 lessons twice a week, half the children reached grade level or above during the second grade and maintained gains at the end of the third grade.

Those who did not reach grade level during the second grade received additional spelling instruction. At the beginning of the third grade, they completed lessons on the six syllable types in English and spelling polysyllabic words. Following this additional spelling instruction, they reached grade level and maintained gains at the end of the third grade (Berninger, Vaughan, Abbott, Brooks, Begay, Curtin et al., 2000). In another study, all schools in a district were randomly assigned to treatment (before- or after-school writing clubs) or control (assessment only). Children in the writing clubs that received specialized handwriting, spelling, and composing instruction improved more than did the controls on the high-stakes test linked to state writing standards (Berninger et al., 2006b, study 4).

Despite this evidence that low-achieving writers respond to explicit writing instruction, studies conducted at the university with school- or parent-referred children who were not responding to reading and spelling instruction at school showed that spelling problems were harder to overcome than decoding problems in reading (Abbott, Reed, Abbott, & Berninger, 1997; Brooks, Vaughan, & Berninger, 1999). Also, children responded more slowly to spelling than other kinds of writing instruction (Berninger, Abbott, Whitaker, Sylvester, & Nolen, 1995). Nevertheless, specialized spelling instruction was effective in helping students with dyslexia (Berninger et al., 2008d; studies 1 and 2).

Automatic correspondences between phonemes and one- or two-letter graphemes were taught in the spelling direction: (a) name pictured word containing target phoneme, (b) say target phoneme that corresponds to the grapheme on a card, and (c) look at and point to the grapheme. In English, there are more phoneme–grapheme correspondences than grapheme–phoneme correspondences, and the correspondences can vary by spelling and reading directions (Berninger, 1998). The warm-up activity was followed by transfer activities in which these correspondences were written, that is, the knowledge was expressed using the orthographic loop to write words and compose written texts to express ideas. Some studies used the previously described orthographic spelling strategies, as also used in the current study, and anagrams (Berninger et al., 2008d, study 1) to improve word-specific orthographic spelling (Olson et al., 1994a, b) in students with dyslexia. Others emphasized phonological spelling strategies (Berninger et al., 2008d, study 2).

Experimental design and research aims

In the current study, we drew upon what we had learned in the prior studies about improving spelling in low-achieving writers and readers in schools (grades 1–4) and in specialized instruction at the university (grades 4–9; age range, 9–15). Students in grades 4 to 9 (n=24) who met the same research criteria for dyslexia as in the multi-generational family genetics study were recruited (impaired decoding and spelling below the mean for age and unexpectedly low for oral verbal reasoning ability; Berninger et al., 2006a) and were randomly assigned to treatment A (n=12) or treatment B (n=12) in an after-school reading-writers' workshop at the university (thirty 1-h sessions twice a week).

The treatments were the same for both groups in step 1 (correspondences between graphemes and phonemes in the reading direction). Thereafter, after step 1 baseline, treatment A introduced new treatments before treatment B received them or treatment B never received them. The two treatments contrasted in each of three sequentially phased in steps: Step 2 taught phoneme–grapheme correspondences for spelling and oral reading (treatment A) OR for oral reading (gpc) plus phonological awareness (treatment B). Step 3 taught orthographic strategies for written spelling and computerized rapid accelerated reading program (RAP) to increase the rate of processing in orthographic working memory (treatment A) OR more step 2 oral reading (gpc) and phonological awareness (treatment B). Step 4 taught morphological strategies plus RAP (treatment A) or introduced orthographic strategies for written spelling (treatment B). Each treatment also had common activities designed to integrate reading and writing, as many school assignments require. The sequentially introduced instructional steps, as often employed in single-subject designs, may have ecological validity for how instruction is delivered in real-world classrooms. Thus, in comparison to other instructional studies that kept all instructional components constant except one that was systematically varied, in this study, the instructional components were phased in sequentially and the new component/s compared with the previous ones (instructional history) within treatments and between treatments.

In keeping with our practices in past research and widely used practices in the schools, instruction was provided within a workshop format with varied activities completed independently and collaboratively and designed to be motivating for struggling writers and readers. Although some workshops focused only on reading (Berninger, Nagy, Carlisle, Thomson, Hoffer, Abbott et al. 2003; Berninger & Wolf, 2009, unit I) or writing (Berninger et al., 2008d, study 1; Berninger & Wolf, 2009, unit II), this one (Berninger & Wolf, 2009, unit IV), like a prior one (Berninger et al., 2008d, study 2; Berninger & Wolf, 2009, unit III) focused on integrated reading–writing, which all students need for school success in the upper elementary grades and middle school (Altemeier, Jones, Abbott, & Berninger, 2006).

Each treatment had a common core of reading and writing activities close in time, which began with teacher-guided oral reading and oral discussion of the reading selection for the lesson (steps 1, 2, or 3) or repeated oral readings (step 4). The reading activity was always followed by a writing activity: written summarization (steps 1, 2, and 3), journal writing or personal reflection about the story (steps 2 and 3), strategies for writing a book review to share personal reflections with others, an audience (steps 2 and 3), or strategies for expository report writing (step 4). Because reading–writing integration requires executive management for the integration of multiple processes (Altemeier, Abbott, & Berninger, 2008), specific strategies were taught for (a) summarizing read material (finding the main idea and supporting details); (b) taking notes while reading source material; and (c) using the notes in idea generation (planning), translating ideas into written language, and reviewing and revising written reports about the read material.

Motivation and intellectual engagement were also taken into account in designing the workshop. Because it is all too easy for struggling writers to give up or avoid writing (Berninger et al., 1995), the curriculum was organized around a "hope theme" that problems can be overcome: Sequoyah, who was physically handicapped, at age 50, invented the Cherokee alphabet and gave his people a written language; the giant redwoods of California were named after him to honor this accomplishment. To foster intellectual engagement, the workshop included a unit on linguistics (the science of how speech can be represented in writing) and a unit on cultural anthropology (comparing the culture of an Iroquois village before 1776[1] and culture of contemporary twenty-first century American life). For example, in step 1, both treatments spent some time learning about the Cherokee language, modeling hand signals as an alternative to a writing system for communication, and examining the Cherokee alphabet in written stories and comparing it to the English alphabet in written stories.

The first research aim was to compare the treatments at the end of each step to determine whether, after instructional component(s) added during that step, (a) treatment A achieved higher than it had in a prior step or pretest and (b) treatment B differed significantly from treatment A. These comparisons were based on target outcomes shown to be hallmark impairments in a family genetics study of dyslexia from which children were recruited—spelling (Rubenstein et al., 2011; Wijsman et al. 2000) and decoding rate (Raskind, Igo, Chapman, Berninger, Thomson, Matsushita et al. 2005). The second research aim was to evaluate whether training with the Breznitz and Nevat (2004) RAP improved reading fluency (accuracy and rate). The computer regulates the rate at which letters in words in text disappear from the monitor while the child reads the text for meaning and answers questions about it.

Method

Participants

Of the 12 participants in each treatment, most were boys (treatment A: ten boys, two girls; treatment B: nine boys, three girls). This gender ratio is consistent with research showing that males with dyslexia are more likely than girls with dyslexia to have writing problems and that gender differences are more likely in writing than reading skills (Berninger, Nielsen, Abbott, Wijsman, & Raskind, 2008b). The grade levels of participants were

[1] The US Constitution is modeled on that of the five nations (Iroquois tribe).

comparable across the treatment groups. Children in grades 4–9 (ages 9–14) who are not responding to the school program vary in instructional levels which do not correspond in a simple way to age or grade; thus, we used normed referenced tests with age- or grade-scaled scores to assess writing and reading achievement on a common metric (means and standard deviations linked to a normal curve) across ages or grades. The sample included, as is reflective of the region where they lived and the nature of dyslexia which occurs in all racial and SES groups, children of Asian American ($n=3$), Hispanic ($n=1$), Pacific Islander ($n=1$), and European American or other white ($n=19$) racial identity. Parental level of education ranged from less than high school (1 father) to high school (2 mothers, 2 fathers), to 1–2 years beyond high school (10 mothers, 9 fathers), to college degree (11 mothers, 9 fathers), and to graduate degree (1 mother, 3 fathers).

Instructional program

Each treatment involved 30 lessons (Berninger & Wolf, 2009, unit IV), which were completed in 1-h sessions twice a week over a 5-month period. Some weeks the groups did not meet or met only once due to vacations or snow days.

During step 1 (six lessons which served as a common baseline across treatments), both treatment groups received instruction designed to improve phonological decoding (gpc) in the reading direction. This approach did not rely on verbalizing rules, which, in our experience, children with dyslexia often do not reliably apply to word decoding or spelling. Rather, procedural knowledge was taught in a way to engage the phonological loop (cross-code naming of letters or written words) and executive functions for focusing, sustaining, and switching attention, as already explained, and for transfer to word reading, word spelling, reading comprehension, or written composition.

During step 1, first, children worked on *automatizing* procedural knowledge of gpc: *graphemes* (one- and two-letter units) and *corresponding phonemes* (in words pictured on cue cards) in the research-based *Talking Letters* program (Berninger, 1998). They looked at and touched a grapheme, named a pictured word, and said the corresponding phoneme in it close in time. They also learned the alternations (other phoneme options for each grapheme) and looking strategies across word positions for written words with final silent *e*. Next, children completed activities to apply this knowledge to decoding a set of made-up pseudowords used repeatedly across lessons. They received immediate teacher feedback (modeling correct response) if errors were made in applying procedural knowledge to decoding. Both time to complete the daily *Talking Letters* and accuracy on the transfer “Jabberwocky” words (containing the same gpc in different word contexts) were plotted on growth graphs so that children and teachers could inspect progress visibly from session to session (Berninger & Abbott, 2003). Finally, they completed the teacher-guided oral reading and discussion of the selection from *Sequoyah the Cherokee Man Who Gave His People Writing* (Rumford, 2004) for that lesson. During step 2, both treatment groups also completed (a) teacher-guided oral reading and discussion for selected passages from *Education of Little Tree*[2] (Carter, 1976) and (b) written summarization activities, journal writing, or a book review.

During step 2 (eight lessons), both treatments continued to receive step 1 treatment, but only treatment A also received alphabetic principle instruction in the spelling direction (phoneme-to-grapheme; e.g., Berninger et al., 2008d, study 1). Treatment B

[2] Although we used carefully selected parts from this book in the current study, the lessons in Berninger and Wolf (2009) for step 2 are based on the reading source used in step 1 because some of the chapters in this book are more appropriate for older students than those who participated in this study.

received phonological awareness treatment (clapping number of syllables in word and holding up fingers for number of phonemes in syllable) using polysyllabic names of rare birds with bird calls for rewards (For The Birds, 2000) without an orthographic component (Berninger et al., 2000; Berninger et al., 2008d, study 2) during the time treatment A received phoneme-to-grapheme instruction.

Comparing treatment A from step 1 to step 2 identifies the within-participant effect of adding alphabetic principle training for spelling to alphabetic principle for oral reading only. Comparing treatments A and B at step 2 identifies the effect of alphabetic principle training for both oral reading and spelling versus oral reading plus phonological awareness training.

During step 3 (four lessons), both groups continued to receive alphabetic principle training (in both reading and spelling direction, treatment A, or in reading only direction, treatment B). In only treatment A were two kinds of word-specific orthographic training (Olson et al., 1994a, b) introduced. First, two strategies were taught for creating a "silent orthography" (e.g., Fayol et al., 1994, 1999a, b) in the mind's eye—Photographic Leprechaun and Proofreaders' Trick (Berninger et al., 2008d, study 1). Words and activities in Berninger and Wolf (2009, unit 2) were used that require creating and accessing precise representations of letters within a specific written word independent of its phonology. Second, children practiced RAP (Breznitz, 1997, 2006, 2008; Breznitz & Nevat, 2004), a computerized silent reading comprehension fluency program which tailors the current presentation to the individual reader's rate and comprehension on prior learning trials. Details of these two approaches to orthographic training are now provided.

For Photographic Leprechaun, a six-step strategy was practiced for each target word on a list of words for a lesson, all of which had letters lacking invariant correspondence to a phoneme: (a) look carefully at the word; (b) name each letter in the written word in a left-to-right direction; (c) take a mental photograph of the word, close eyes, and hold a mental photograph of the word in mind's eye (i.e., visualize it internally); (d) name the letter or letters in designated word positions (e.g., the third and fourth letters in *sight* or the second letter in *know*); (e) open eyes and check target word on the list to find out whether the correct letter(s) is identified; and (f) listen to teacher feedback about correct letter(s) for designated position(s).

For the Proofreaders' Trick, the same set of words was practiced with this three-step strategy : (a) study the written word carefully; (b) hold word in the "mind's eye" while spelling them silently backwards with "inside voice"; and(c) open eyes and check spelling in backwards direction against forward spelling of target written. These two strategies were repeated for each word on the list for the daily lesson.

For RAP (Breznitz, 1997, 2006), individuals took a pretest that identified the rate at which they could read short passages and answer comprehension questions at criterion levels of accuracy. Then, the computer program individually tailored the rate of passage presentation to each individual's pretest rate by setting it somewhat faster. At the end of each session, the computer program assessed comprehension for that rate and, if comprehension met criterion, set the rate of presentation somewhat faster for the next time, or, if comprehension did not meet criterion, set the rate of presentations somewhat lower for the next time. The rate of passage presentation was controlled by the rate at which individual letters disappeared from the words in the written text displayed on the monitor, thus requiring the readers to attend to the written words and access accumulating amounts of the written text in their mind's eye (visible language in working memory) while reading the text for meaning. Thus, this accelerated reading fluency training program might facilitate the efficiency of orthographic working memory while training *silent* reading comprehension accuracy and fluency. Most reading beginning in fourth grade and thereafter is silent. During step 3, both treatments also completed (a) teacher-guided oral reading and discussion for selections from *Education of Little Tree*[2] (Carter, 1976) and (b) written summarization activities, journal writing, or a book review.

Comparing treatment A from step 1 to step 3 identifies the within-participant effect of adding orthographic spelling strategies and orthographic working memory training (for reading comprehension) to alphabetic principle training (reading plus spelling direction). Comparing treatment A to treatment B at step 3 identifies the between-participant effect of adding orthographic training to alphabetic principle and phonological awareness treatment.

During step 4 (12 lessons), alphabetic principle training (grapheme–phoneme correspondences) was discontinued in both treatments. In treatment A, sorts were introduced to develop morphological awareness and coordination of morphology with orthography and phonology through sorting words into exemplar categories (Berninger et al., 2003; Berninger & Wolf, 2009, units I and IV) and orthographic working memory training for comprehension continued. Sorts involved inflectional and derivational suffixes and true versus foil prefixes and suffixes, and thinking about whether morphological, orthographic, and phonological cues were related in specific written words. In treatment B, two silent orthographic strategies—Photographic Leprechauns and Proofreaders' Trick—were introduced; no RAP or morphological treatment was provided. During step 4, both treatments also completed (a) teacher-guided oral reading and discussion of selections from *If You Lived with the Iroquois*[1] (Levine, 1999), (b) oral reading fluency activities,[3] and (c) learning and applying self-regulation strategies for report writing and expository genre writing activities.

Comparing treatment A from pretest before step 1 to step 4 identifies the within-participant effect of adding morphological awareness to an instructional history that includes alphabetic principle training in both the reading and spelling direction and orthographic strategies and orthographic working memory training with only orthographic working memory training continuing. Comparing treatments A and B at step 4 identifies between-participant effects for introducing morphological strategy training compared to introducing orthographic strategy training without orthographic working memory training and withdrawing alphabetic principle training from both treatments.

Training of teaching assistants and fidelity of treatment implementation

Two teachers worked with each group of six students in each treatment. These teachers completed training by the first author prior to beginning the intervention study. In addition, training sessions were held with the teachers prior to the beginning of each session. Fidelity of treatment implementation was monitored constantly during the sessions, with coaching and reminding on the spot if needed to ensure compliance with instructional procedures. Then, at the end of each session, any noted problems were discussed to ensure that all tutors understood how the instructional activities were to be implemented with fidelity. This "on the spot" and "end of session" monitoring covered all instructional components and assessments (probes in lessons, pretest, and tests at end of blocks). Although problems seldom arose after the initial session, we kept up

[3] Treatment A did repeated oral readings using scanned pages from *If I Lived in an Iroquois Village*. Children read orally as one word at a time was highlighted and synchronized with child's oral reading rate during the rereadings. Kurzweil software was used for scanning, highlighting, and synchronizing the rate. Treatment B did repeated readings in the *Reading Naturally* (Ihnot, 1997) hard copy version. Treatment groups did not differ significantly in either silent reading fluency measure given.

this high level of self-monitoring throughout the entire workshop, consistent with approach to treatment fidelity in our past instructional studies in which we do not rely solely on spot checks with quantitative ratings.

Measures

All the following tests have acceptable reliability (see test manuals) and validity and are used in schools and research (see Berninger et al., 2006; Berninger et al., 2008d). They were all administered and scored according to procedures in test manuals.

Pseudoword dictated spelling accuracy (phonological spelling) For the *Woodcock Johnson, Third Edition* (WJ III) Spell Sounds subtest (Woodcock, McGrew, & Mather, 2001), students wrote dictated pseudowords. Correct spellings required both knowledge of alphabetic principle (phoneme–grapheme correspondences in the spelling direction) and phonotactic/orthotactic relationships (e.g., positional knowledge such as spelling the /s/ sound at the end of the word, which might involve double *s* rather than a single *s*, as in ki*ss*).

Real word dictated spelling For the *Wechsler Individual Achievement Test, 2nd Edition (WIAT II)* (Psychological Corporation, 2001) Spelling subtest, students wrote dictated real words, which the examiner pronounced alone, then used in a sentence to provide contextual meaning, and then pronounced alone.

Timed, accurate word choice (word-specific orthographic spelling) For the *Process Assessment of the Learner* (PAL; Berninger, 2001)[4] Word Choice subtest, which is an adaptation of Olson et al. (1994a, b, 1999), validated in cross-sectional writing research (Berninger, Cartwright, Yates, Swanson, & Abbott, 1994), students selected the correctly spelled words among three phonological equivalents (pseudohomonyms, which when pronounced sound the same as the correctly spelled real word). Unlike the dictated spelling measures, handwriting is not required to reproduce the correct spelling.

Accurate, automatic letter writing PAL alphabet writing task (Berninger, 2001; see footnote 4) was also given. Children are asked to print the alphabet as accurately and quickly as they can in order. It is scored for number of legible letters in correct order in the first 15 s.

Compositional fluency For *WJ III Writing Fluency* (Woodcock et al., 2001), children are shown three words (or pictures of words) and asked to construct as many sentences as they can within 7 min. Sentences are scored for grammatical acceptability and use of each of the three words without transforming them grammatically.

Phonological decoding rate For the *Kaufman Test of Educational Achievement, 2nd Edition* (Kaufman & Kaufman, 2004) Decoding Fluency subtest, students pronounced pseudowords on a list as accurately and as quickly as they could within 1 min.

[4] This test was revised and renormed with scaled scores for all subtests in 2007.

Silent reading fluency For the *Test of Silent Word Reading Fluency* (Mather, Hammill, Allen, & Roberts, 2004), students drew boundary lines for words embedded in strings of continuous letters on this timed test. For *PAL Sentence Sense* (Berninger, 2001; see footnote 4), students circled the number of one of three sentences (composed of only real words) that was a meaningful sentence that made sense.

Verbal IQ For the verbal comprehension factor (information, vocabulary, similarities, and comprehension) of the *Wechsler Individual Achievement Test*, *3rd Edition* (Wechsler, 1991) used to assess verbal intelligence, children answered factual questions, explained what words mean, explained how two words were the same in meaning, and answered questions to show understanding of the world around them.

Results

Comparisons of treatments A and B

Pretest differences

Treatments A and B did not differ significantly on pretest measures of either target outcome—spelling (pseudoword or real word; see Table 1)—or phonological decoding rate (see Table 2).

Main effects for time showing both groups improved

Both treatment groups A and B improved significantly from pretest to posttest on dictated real word spelling (Table 1) and phonological decoding rate (Table 2), but not pseudoword spelling (Table 1). They also improved significantly from pretest to end of step 4 in automatic letter writing ($F(1,20)=20.52$, $p<0.001$). Writing fluency improved significantly over that same time period on a one-tail directional test ($F(1,20)=3.61$, $p=0.072$).

Time by treatment interaction effects

No significant time × treatment interaction was found for any of the comparisons from pretest at beginning of step 1 to the end of the other steps as described earlier in the methods for any spelling measure (real words or pseudowords). However, the time × treatment interaction was significant for rate of phonological decoding for comparisons from pretest to end of certain steps as described next (also see Table 2). This finding again shows that word decoding is easier to remediate than spelling in students with dyslexia, which is why they need extra, not less, help with spelling (see Berninger et al., 2008b, discussed in the introduction).

For end of step 1, the time × treatment interaction was not significant for phonological decoding rate. Thus, teaching grapheme–phoneme correspondences in alphabetic principle in the eye-to-mouth direction for oral reading (phonological loop) benefited both treatments comparably.

For end of step 2, the time × treatment interaction was not significant for phonological decoding rate at end of step 2. Thus, teaching alphabetic principle by engaging both the phonological loop and orthographic loop (treatment A) did not have a relative advantage for

Table 1 ANOVAs for WJ III spell sounds and WIAT II spelling (see text for explanation of steps)

	M	SD	Time	Time × treatment
WJ III spell sounds (pseudowords)				
Pretest				
$F(1,22)=2.24$, $p=0.15$				
Treatment A	89.75	7.24		
Treatment B	78.00	26.25		
End step 2				
Treatment A	89.91	8.93		
Treatment B	88.08	9.89		
Pretest to end step 2			$F(1,21)=1.55$ $p=0.23$	$F(1,21)=1.44$ $p=0.24$
End step 3				
Treatment A	89.67	9.39		
Treatment B	88.92	10.16		
Pretest to end step 3			$F(1,22)=1.93$ $p=0.18$	$F(1,22)=1.99$ $p=0.17$
End step 4				
Treatment A	91.08	11.54		
Treatment B	89.36	10.66		
Pretest to end step 4			$F(1,21)=2.68$ $p=0.12$	$F(1,21)=1.73$ $p=0.21$
WIAT II spelling (real words)				
Pretest				
$F(1,22)=1.14$ $p=0.30$				
Treatment A	82.42	8.63		
Treatment B	77.17	14.68		
End step 3				
Treatment A	86.17	9.40		
Treatment B	79.00	12.35		
Pretest to end step 3			$F(1,22)=6.95$ $p=.0015$	$F(1,22)=0.92$ $p=0.35$
End step 4				
Treatment A	85.67	9.81		
Treatment B	79.55	12.22		
Pretest to end step 4			$F(1,21)=6.94$, $p=0.015$	$F(1,21)=0.14$, $p=0.72$

this outcome compared with engaging only the phonological loop (treatment B), nor did teaching phonological awareness in addition to teaching alphabetic principle (treatment B). These findings contrasted with prior spelling intervention that focused more on phonological strategies (Berninger et al., 2008, study 2) than did the current study which focused on the benefits of adding orthographic strategies. However, in the current study, both treatment groups improved on the behavioral measure of phonological decoding rate at end of step 2 compared with pretest; both groups continued to receive alphabetic principle training and teacher-guided reading and writing instruction during step 2.

For end of step 3, a significant time × treatment interaction was observed: Treatment A improved more than treatment B in phonological decoding rate after two silent orthography spelling strategies (Photographic Leprechaun and Proofreaders' Trick) and Breznitz and

Table 2 ANOVAs for KTEA-2 phonological decoding rate (standard scores for age, see text for explanation of steps in sequenced treatment)

	M	SD	Time	Time × treatment
Pretest				
$F(1,22)=1.66$, $p=0.21$				
Treatment A	83.75	11.94		
Treatment B	77.33	12.44		
End step 1				
Treatment A	88.33	10.82		
Treatment B	79.75	14.60		
Pretest to end step 1			$F(1,22)=5.59$ $p=0.027$	$F(1,22)=0.54$, $p=0.47$ ns
End step 3				
Treatment A	94.25	10.45		
Treatment B	81.33	14.73		
Pretest to end step 3			$F(1,22)=22.80$, $p<0.001$	$F(1,22)=4.58$, $p=0.044$
End step 4[c]				
Treatment A	93.42	12.11		
Treatment B	86.36	12.35		
Pretest to end step 4[c]			$F(1,21)=39.50$, $p<0.001$	$F(1,21)=.04$, $p=0.85$

p values at or less than .05 are statistically significant

Nevat's (2004) accelerated orthographic working memory rate training for silent reading comprehension were introduced. Both treatments had continued to receive alphabetic principle training (gpc) and teacher-guided reading and writing activities during step 3.

For end of step 4, the time × treatment interaction at the end of step 4 was not significant for phonological decoding rate when treatment A was given morphological strategy instructional activities for coordinated orthographic, phonological, and morphological relationships and continued to receive orthographic working memory training, and treatment B used the newly introduced two orthographic spelling strategies. Neither treatment A nor treatment B received any alphabetic principle training (gpc) during step 4. Although no significant treatment-specific effect was found for phonological decoding rate, it is worth noting that treatment A's mean phonological decoding rate decreased in step 4 when no alphabetic principle training was provided compared with step 3 when alphabetic principle training was provided. Children with dyslexia may need sustained work to coordinate phonological and orthographic correspondences with each other if they are also to coordinate them with morphology.

Yet, for treatment B, which also received no alphabetic principle training but began to receive orthographic strategy training during step 4, the mean phonological coding rate increased in magnitude from step 3 to step 4. This effect specific to treatment B suggests that adding word-specific orthographic spelling training to alphabetic principle and phonological awareness training may benefit the rate of phonological decoding (which has a genetic basis in dyslexia; Raskind et al., 2005).

Multiple regressions for real word spelling outcome

No treatment-specific effect was found for either spelling measure, but the standard deviations were relatively large, indicating sizable individual differences among the students, as is expected given the genetic basis for spelling problems in dyslexia; children may vary in how many genetic variations they have that interfere with spelling learning. However, normed measures for age and grade allowed us to compare children across grade levels on a common metric for comparing relative abilities across age or grades (scaled scores for means of 100 or 10 and standard deviations of 15 or 3, respectively). Thus, multiple regressions were performed to evaluate whether individual differences of some measures or treatment (instructional steps) might be mediating response to reading–writing instruction on spelling dictated real words. In these regressions, a constant set of predictors (phonological/pseudoword spelling, orthographic spelling/word choice, verbal IQ, and treatment group) was used to evaluate this spelling outcome across the blocks of the instructional study (see Table 3). As shown in Table 3, results changed from pretest to end of step 3 to end of step 4, and the percent variance explained by the set of predictors increased across the steps.

At pretest, orthographic spelling (word choice) contributed uniquely, and the contribution of verbal IQ was marginally significant. At the end of step 3, all predictors (three measures of individual differences and one related to treatment) contributed uniquely. This result is consistent with the prior finding that the time × treatment interaction was significant at the end of step 3 after three orthographic treatments (two spelling strategies and RAP that affects the rate of orthographic working memory processing during silent reading comprehension) had been introduced; of all the phased-in instructional components, the set introduced in step 3 seemed to show the most treatment-specific effects in this experimental design—for both reading (word decoding rate) and writing (real word spelling). At the end of step 4, only the phonological and orthographic spelling measures contributed significantly to the regression. Treatment may not have contributed uniquely at end of step 4 because alphabetic principle training ceased in both treatments in this final step.

Accelerated orthographic working memory training

Table 4 summarizes the results for rate of letter processing during orthographic working memory training that controls the rate at which a letter in a word in a text disappears one letter at a time. Results are reported only for treatment A, which was the only treatment given this training during steps 3 and 4. As shown in Table 4, as a group, treatment A improved significantly in the rate of letter processing: threefold from the beginning to the end of step 3 and fivefold from the beginning of step 3 to end of step 4. The group did not improve significantly in answering comprehension questions during the acceleration training, but a

Table 3 Multiple regression for WIAT II dependent measure (learning outcome) predicted from a common set of independent measures (predictors) at the end of different steps of the reading-writers' workshop (WJ III spell sounds = phonological spelling; PAL word choice = orthographic spelling; verbal IQ = VIQ; treatment = A versus B; see text for explanation of the different steps)

	Pretest		End of step 3		End of step 4	
Multiple regression	$F(4,19)=6.30$, $p=0.002$		$F(4,19)=15.01$, $p<0.001$		$F(4,18)=15.98$, $p<0.001$	
Explained variance (R^2)	0.57		0.76		0.78	
Predictors	*t*	*p*	*t*	*p*	*t*	*p*
Phonological spelling	1.09	0.29	3.12	0.006	2.55	0.02
Orthographic spelling	2.99	0.008	3.37	0.003	3.45	0.003
Verbal IQ	2.04	0.056	3.14	0.005	1.50	0.15
Treatment	−0.48	0.64	−2.44	0.025	−1.20	0.25

Table 4 Changes in letter processing rate (letters per minute) from before step 3 to end of step 3 and step 4 treatments for treatment A (n=12, see text for explanation of different steps)

	M	SD	t	df	p value
Letter rate[a]					
Beginning	10.50	5.23			
Step 3					
End	30.00	19.92	−4.14	11	0.002
Step 3					
End	53.50	38.16	−4.34	11	0.001
Step 4					
Reading comprehension[b]					
Beginning	18.42	4.98			
Step 3					
End	18.50	5.44	−0.17	11	n.s.
Step 3					
End	19.08	5.78	−0.85	11	n.s.
Step 4					

[a] Rate at which single letters disappear from text while it is read silently is adjusted from trial to trial according to accuracy in answering comprehension question

[b] Ceiling is 24 because there are 24 comprehension questions that affect whether the rate of text presentation (at which a letter disappears from text) is adjusted upwards or downwards

trend toward improvement is evident, from 76.7% to 80% (see Table 4). Observation of individual performance patterns showed that two thirds of treatment A participants (8 of 12) had higher reading rate and comprehension scores at posttest than at pretest.

The rate of letter processing was significantly correlated with two behavioral measures of silent reading fluency administered at the end of steps 3 and 4. At the end of step 3, the rate of letter processing in orthographic working memory was significantly correlated with silent word reading fluency (r=0.60, p=0.052; Mather et al., 2004) and with silent sentence reading fluency (r=0.61, p=0.049; Berninger, 2001; see footnote 4). At the end of step 4, the rate of letter processing in orthographic working memory was significantly correlated with silent word reading fluency (r=0.69, p=0.02; Mather et al., 2004) and with silent sentence reading fluency (r=0.70, p=0.017; Berninger, 2001; see footnote 4).

Treatment A showed a significant improvement in silent word reading fluency from beginning of step 3 (M=94.04, SD=17.87) to end of block 4 (M=96.44, SD=18.22; $F(1,22)$=26.43, p<0.001). Likewise, treatment A showed a significant improvement in silent sentence reading fluency from beginning of step 3 (M=−0.51, SD=1.15) to end of step 4 (M=−0.47, SD=1.15; $F(1,22)$=5.83, p=0.025).

Discussion

Replicating three past research findings

The current results are consistent with three prior research findings. First, teaching silent orthography strategies normalized brain function on spelling tasks (Richards et al., 2006) and facilitated written word decoding rate (Berninger et al., 2008d, study 2) in a morphophonemic orthography in which graphemes do not always have phoneme correspondences as, for example, in French (Fayol et al., 1994, 1999a, b, 2006) or English.

Second, treatment A showed significantly more improvement than treatment B in phonological decoding rate only when comprehensive orthographic treatment was introduced in block 3. This finding is consistent with earlier reports of a relationship between orthographic coding and reading fluency (Bowers, 1993, Bowers & Wolf, 1993).

Third, computerized accelerated silent reading comprehension training, which individually tailored the timing of written material presentation to individual's orthographic working memory, increased the rate of letter processing, which in turn was correlated with two independent measures of silent reading fluency in a study that lasted longer than many prior RAP studies (e.g., Breznitz, 1997, 2001, 2006; Breznitz & Share, 1992); this finding adds to the accumulating evidence that RAP warrants further research for treating reading fluency problems in children with dyslexia. Two thirds of participants showed improvement in both RAP reading comprehension accuracy and reading rate measures. Individual's RAP times also correlated significantly with two measures of silent reading fluency at the end of step 4.

Five new instructional findings: implications for overcoming core dyslexia deficits in phonological decoding rate and spelling

We used a group research design that sequentially phased-in instructional components and incorporated a single-subject methodology—a common baseline followed by observing effects after treatments were introduced and then in some cases withdrawn. Three significant findings and two null findings have implications for designing future studies to evaluate if findings replicate and to extend the current research in ways that have significance for theory and practice.

Statistically significant findings

First, the multiple regressions for dictated real word spelling provided evidence that the comprehensive orthographic treatment (word-specific orthography strategy training and timing of orthographic working memory during silent reading) in step 3 contributed uniquely to the outcome for spelling dictated real words. This effect was observed following an instructional history that taught alphabetic principle (grapheme–phoneme correspondence) in both the reading and spelling direction following teaching it only in a reading direction. This finding meshes with that observed in a follow-up study to the longitudinal study of phonological, orthographic, and morphological growth curves during the first four grades (Berninger et al., 2010). When growth curves for phonology (phoneme tasks), morphology, and receptive orthographic coding (which cannot be completed successfully based on phonology alone and does not require reading) were entered as simultaneous predictors, only the orthographic growth curve uniquely predicted the fourth grade real word and pseudoword spelling achievement outcome (Berninger et al., 2011). The orthographic word form may have a unique capability for integrating the interrelationships among all three linguistic word form codes in a silent orthographic representation (see studies by Fayol earlier in the chapter) that underlies word-specific orthographic spelling (Olson et al. 1994a, b).

Second, treatment A lost its relative advantage for improved phonological decoding rate during step 4 when all alphabetic principle training was omitted. Thus, orthographic coding may be necessary, but not sufficient, and alphabetic principle treatment may be necessary, but not sufficient, to overcome one of the core deficits in dyslexia—phonological decoding rate. The practical significance is that individuals with dyslexia benefit from both kinds of instruction: (a) orthographic–phonological correspondences in alphabetic principle and (b) word-specific orthographic spelling strategies.

Third, the RAP findings not only replicate past research about its effectiveness in improving silent reading fluency but also support new understanding about RAP's potential effectiveness for improving the timing and related efficiency of orthographic working memory—holding time-limited written words and their letters in mind while processing them for meaning. That the training improved the rate of letter processing, which was correlated with two silent reading comprehension fluency measures, warrants further research on the role of orthographic working memory in silent reading comprehension rate and accommodation needs of students with dyslexia for extra time on silent reading tests. The accelerated reading may exert its effects on reading fluency via orthographic working memory (Breznitz & Share, 1992) by accelerating the rate of letter processing in orthographic working memory (Crosson et al., 1999). A collaborative research project, funded by the Binational Science Foundation (P.I. Zvia Breznitz, University of Haifa; Co-PI, Virginia Berninger, University of Washington), is investigating this issue in a larger study of writing and reading fluency.

Null findings

The significance of results also depends on how they fit into an accumulating body of knowledge and may inform future research directions to add to that body of knowledge. Null findings serve both purposes in creating a scientific understanding of effective instructional approaches for overcoming developmental dyslexia. In contrast to past findings, training phoneme–orthographic correspondences in both the reading and spelling direction did not have an advantage over only training in the reading direction. That result may be because treatment A did not receive any phonological awareness treatment as in the past studies that also trained correspondences in both the reading and spelling direction (e.g., Berninger et al., 2008d, study 2; Richards & Berninger, 2008). Future research might address whether phonological awareness plus training alphabetic principle in both the reading and spelling directions has a special advantage.

The null finding for adding morphology in step 4 of treatment A was surprising given research showing that morphological awareness is an important treatment component in French-speaking (Casalis and Louis-Alexandre, 2000) and English-speaking (Berninger et al., 2003) children with dyslexia. We offer three possible explanations for future research to explore. Because children with dyslexia are more likely to have phonological and orthographic deficits than morphological deficits (Berninger et al., 2006), the orthographic strategies introduced in step 3 may have facilitated their abstractions of both morphological and orthographic regularities (cf., Nunes & Bryant, 2006; Pacton et al., 2005) and masked benefits of sorts to increase morphological awareness when added in step 4 of treatment A. The second explanation is that the step 4 morphological strategy treatment was not sufficiently long to observe its added benefits. That is a real possibility because the participants reported that these were novel activities not taught at school. The third explanation is that by withdrawing the alphabetic principle at the end, we have interfered with developing knowledge of the interrelationships among phonology, orthography, and morphology. We predict that children with selective language impairment who are often very impaired in morphology would require and benefit from substantial and sustained training in morphological awareness (see Silliman & Berninger, 2011 and other articles in that special issue).

Raising new issues for instructional research

More research is needed on effective instruction for overcoming the working memory impairments in children with dyslexia or other specific learning disabilities (e.g., Baddeley, Gathercole, & Papagno, 1998; Swanson, 1999; Swanson & Siegel, 2001). Because children with dyslexia may vary in which working memory components are impaired (phonological, orthographic, or morphological word storage and processing units, phonological or orthographic loops, or specific executive functions for supervisory attention), different instructional components may be found to be effective depending on the individual's profile of specific working memory impairments (see Silliman & Berninger, 2011).

At this stage of developing programmatic research on effective writing instruction for children with dyslexia, attention should be given to the following issues:

(a) *Conceptual foundations*—which metacognitive/executive function, cognitive, language, memory, or motor processes are likely to be facilitated by the instruction
(b) *Applications to individuals*—research that informs not only "what works for teaching reading in general for children with and without dyslexia" but also "what works for whom—the individual case"
(c) *Precisely defined samples*—so it is clear to whom the results can be generalized
(d) *Ecological validity*—ease and feasibility of implementing the interventions in classroom settings so that students with dyslexia are not denied access to the regular curriculum across content subject areas

Given the individual differences in learning profiles of students in general and with dyslexia in particular, it is unlikely that there is just one treatment that works for all. Moreover, effective instruction in real-world classrooms has multiple components and is sequenced over time. In this era of evidence-based practices, critical consumers of the research literature should be very cautious of meta-analyses that are not based on studies in which participants met the same well-specified inclusion criteria[5] and research designs and questions and measures are comparable; otherwise, it is not possible to know how to generalize or interpret findings based on effect size (for further discussion, see Berninger, Rijlaarsdam, & Fayol, in press b).

Significance for the theme of this special issue

Additional research to find effective and enduring improvement in spelling and related handwriting and composing skills in individuals with carefully diagnosed developmental dyslexia should be a high priority. In the current study, the amount of improvement was larger for phonological decoding rate (about 2/3 SD from pretest to end of step 4 for

[5] For treatment-relevant, differential diagnosis of dysgraphia, dyslexia, and oral and written language learning disability within a working memory model with three word forms and syntax storage and processing units, phonological and orthographic loops, and a panel of executive functions for self-regulating the writing and reading process (inhibition/focus, switching/flexibility, sustaining, self-monitoring and updating), see Berninger (2008), Silliman and Berninger (2011), and Berninger slide charts posted on the IDA web site for Symposium on Working Memory organized by Michele Berg and presented 27 October 2010 at the International Dyslexia Association, Phoenix Convention Center, Phoenix, AZ.

treatment A; see Table 2) than for spelling dictated real words (slightly more than 1/5 SD from pretest to end of step 4; see Table 1).

Word-specific orthographic spelling and phonological decoding were the only skills in the set of predictors in multiple regression, which also included spelling pseudowords, verbal IQ, and treatment, that consistently contributed uniquely to dictated real word spelling. A prevailing claim that dyslexia is due only to phonological deficits should be revised to include not only phonological deficits but also orthographic spelling deficits. By denying the evidence-based orthographic basis of dyslexia, affected individuals may not receive appropriate treatment, including strategies for silent orthography, which affects both their reading and spelling skills. Although invented spellings are normal during the preschool and early school years, spelling development benefits from feedback for conventional spellings beginning in the early grades (Rieben, Ntamakiliro, Gonthier, & Fayol, 2005). Olson and colleagues (e.g., Olson et al., 1994a, b, 1999) made a valuable contribution to the field of dyslexia by documenting the importance of non-phonological, word-specific orthographic representations, as also did Fayol and his colleagues to the field of writing research.

Considerable evidence also exists that good, average, and poor spellers differ in their morphological, phonological, and orthographic skills (Garcia, Abbott, & Berninger, 2010). Both typically developing readers and writers and those with dyslexia draw on the interrelationships among morphology, orthography, and phonology in learning to spell and read (Berninger, Raskind et al., 2008). Often, but not always, we found that adding morphological awareness was the key to improving reading skill.

Much research remains to figure out the science of the best *ways* to teach children with dyslexia to integrate within their working memory for purposes of learning and using written language and related aural and oral language (Berninger et al., 2010b):

- Storage and processing of words and their phonology, orthography, and morphology codes and of syntax for accumulating words
- Loops for coordinating internal language codes with their motor output organs—mouths and hands—and sensory input organs—ears for auditory and vestibular (location in space related to movement) sensation, and eyes for visual sensation, and skin for touch and kinesthetic (touch for serial movement) sensation; and
- The panel of executive functions for supervising and supporting the integration of attention (focusing, switching, sustaining), language, and motor processes with cognitive processes for thinking and meaning-making.

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