Received: 26 October 2020 | Revised: 28 April 2021 | Accepted: 17 August 2021

DOI: 10.1002/dys.1695

RESEARCH ARTICLE

WILEY

Improving English reading fluency and comprehension for children with reading fluency disabilities

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Funding information
Gail & Stephen Jarislowsky Research Endowment - MSVU

In the English language, students who read words accurately but have impairments in reading fluency are under-studied. The associated difficulties they have with comprehending text make it particularly important to delineate effective interventions for these students. Counter to suggestions that these readers need interventions focused on text reading, we examined the effects of a decoding-focused intervention. The intervention targeted decoding-related skills, including speeded training on sublexical spelling patterns. We examined the efficacy of this program for students with fluency-defined disabilities, and compared gains to those for students with accuracy-defined disabilities. In the initial phase of the program, readers with fluency-defined disabilities made greater gains in fluency, while readers with accuracy-defined disabilities made larger gains in word reading accuracy. The mean fluency score for readers with fluency-defined disabilities came within the average range across the intervention, as did reading comprehension for both groups. Readers' mastery on speeded learning of sublexical spelling patterns predicted unique variance in fluency outcomes, beyond variance accounted for by pre-test fluency and word reading accuracy. The results support intervention approaches focused on decoding-related skills for students who have fluency-defined disabilities and are consistent with theories of reading fluency that identify a role for automaticity with sublexical spelling patterns.

KEYWORDS
dyslexia, fluency interventions, reading disabilities, reading fluency, reading remediation

Practitioner points

- A decoding-focused intervention was effective for remediating reading fluency and comprehension for students with specific reading fluency disabilities.
- To improve fluency, it may be best to initially focus decoding-related skills on the accuracy, and then to target speed and automaticity.
- Speeded practice with many orthographic patterns that make up words may well contribute to remediating fluency deficits in students with reading disabilities.

1 | INTRODUCTION

Skilled readers recognize words in the text quickly and seemingly effortlessly, allowing cognitive resources to be directed at the higher-level, meaning-making goals of reading (LaBerge & Samuels, 1974; Perfetti, 2007). According to verbal efficiency theory, reading comprehension is related to the accuracy and speed of word reading, two indicators of automaticity (Perfetti, 1988). Theories of reading acquisition delineate this development of word reading automaticity (e.g., Ehri, 1998, 2014; Share, 2008) and its critical role in reading fluency (e.g., R. F. Hudson, Pullen, Lane, & Torgesen, 2008; R. F. Hudson, Torgesen, Lane, & Turner, 2012; Norton & Wolf, 2012). Reading fluency is frequently defined as the accuracy and speed of oral text reading, consistent with our use of the term in this paper (for reviews, see Chard, Vaughn, & Tyler, 2002; Chard, Ketterlin-Geller, Baker, Doabler, & Apichatabutra, 2009; A. Hudson, Koh, Moore, & Binks-Cantrell, 2020; National Reading Panel, 2000; Therrien, 2004; cf. Pikulski & Chard, 2005).

Difficulties in the two identified aspects of developing word reading automaticity, accuracy and speed, are central to our understanding of reading disabilities. In the English language, dyslexia or reading disabilities are most often defined as significant deficits in accurate word reading. This group is characterized by *both* inaccurate and severely dysfluent text reading (Torgesen & Hudson, 2006). In orthographies with more consistency between graphemes and phonemes (e.g., Finnish, Dutch, and German), students with dyslexia most often read words accurately but have severe deficits in reading fluency (Landerl & Wimmer, 2008; Moll, Gangl, Banfi, Schulte-Körne, & Landerl, 2020). A less well-studied group of readers in English has also been identified with fluency deficits alongside accurate word reading (e.g., Brasseur-Hock, Hock, Kieffer, Biancarosa, & Deshler, 2011; Lovett, Ransby, & Barron, 1988). Researchers have argued that readers with deficits specific to fluency will need a starkly different type of intervention than readers with poor accuracy, one focused on reading beyond the word level (e.g., Brasseur-Hock et al., 2011; Pikulski & Chard, 2005). In this paper, we argue that decoding-focused interventions are appropriate for readers with specific reading fluency disabilities and we examine the effects of one such program.

Decoding-focused and multicomponent interventions have been shown to be effective with students with accuracy-defined reading disabilities (e.g., Lovett, Lacerenza, & Borden, 2000; Rashotte, MacPhee, & Torgesen, 2001; Wolf et al., 2009); however, even when achievement gaps for word reading accuracy and comprehension are reduced or eliminated, fluency deficits have remained stable and far below average for these readers (for review, see Torgesen & Hudson, 2006). Conclusions from research to date are that fluency achievement is "notoriously difficult to improve …" (Norton & Wolf, 2012, p. 447).

There is much less research on remediation for English language readers with fluency deficits but accurate word reading. Research on text-level interventions, claimed to be necessary to remediate fluency deficits (e.g., National Reading Panel, 2000; Pikulski & Chard, 2005), has focused on connected text reading and rereading (e.g., Field, Begeny, & Kyung Kim, 2019; for review see A. Hudson et al., 2020). Meta-analyses on repeated reading interventions have generally reported moderate effect sizes for students with learning disabilities (the type of learning disability or reading profile has not always been well defined, e.g., O'Connor, 2018), with smaller effects for novel versus practiced texts (Therrien, 2004) and for standardized versus experimental measures (Scammacca, Roberts, Vaughn, & Stuebing, 2013). Evidence for generalized effects with such text-reading interventions is mixed, and two research syntheses concluded that repeated reading does not have enough support to be considered an evidence-based intervention (Chard et al., 2009; O'Keeffe, Slocum, Burlingame, Snyder, & Bundock, 2012; cf. A. Hudson et al., 2020). It has been recognized that the field needs stronger evidence concerning how to remediate fluency deficits (Fraga González et al., 2015).

For the most part, studies that focus on improving word reading deficits have been excluded from meta-analyses and qualitative reviews on fluency interventions (e.g., A. Hudson et al., 2020; National Reading Panel, 2000). Furthermore, the fluency gains in word-focused studies may be viewed as a by-product, rather than an aim of instruction (Chard et al., 2002). Empirical research, however, has borne out the theoretical notion that accuracy and speed of reading individual words are critical components, and perhaps the primary drivers, of fluent text reading (e.g., Torgesen & Hudson, 2006; Lipka, 2017). For example, accuracy and rate of reading lists of words (single word reading efficiency) consistently contributed the greatest amount of variance to oral text-reading fluency across samples of children with accuracy-defined reading disabilities and for more normally distributed samples (Torgesen, Rashotte, & Alexander, 2001; see also O'Brien, Wolf, Miller, Lovett, & Morris, 2011). Accuracy and rate of reading pseudowords also contributed unique variance to fluent text reading beyond single word reading efficiency in these samples (Torgesen et al., 2001). This finding suggests that sublexical decoding processes are also important to text reading fluency, as pseudowords cannot be recognized based on a stored, word-level representation. This is consistent with models of word reading acquisition (Ehri, 2014; Seidenberg & McClelland, 1989; Share, 2008) for which fast and effortless word reading is driven by stored connections between sounds and spellings of graphemes, bigrams, trigrams, and larger units, such as syllables and morphemes within words, as well as associated word-position information (see also, Berninger, Abbott, Vermeulen, & Fulton, 2006).

Taken together, these findings and theories support the proposal that increasing readers' efficiency with word and sublexical reading could well benefit readers with accurate but dysfluent reading. That is, fluency interventions may not need to focus beyond the word level for these readers, as suggested by some (e.g., Brasseur-Hock et al., 2011; Pikulski & Chard, 2005). For students with reading disabilities in more transparent orthographies, for whom reading fluency is the major deficit, brief training with sublexical sound-spelling mappings has been one research focus. This training has been studied for syllable mappings (e.g., Heikkilä, Aro, Närhi, Westerholm, & Ahonen, 2013; Huemer, Aro, Landerl, & Lyytinen, 2010), onset and consonant-cluster mappings (e.g., Hintikka, Landerl, Aro, & Lyytinen, 2008; Thaler, Ebner, Wimmer, & Landerl, 2004), and individual sound-letter mappings (e.g., Marinus, de Jong, & van der Leij, 2012). In general, speeded training with these various sublexical units presented in isolation or within words resulted in faster recognition of trained and untrained words containing the letter clusters (e.g., Hintikka et al., 2008; Thaler et al., 2004, cf. Marinus et al., 2012). These effects have typically not generalized to words without the trained letter clusters or to oral text reading fluency (e.g., Hintikka et al., 2008; Huemer et al., 2010; Thaler et al., 2004). This research supports the proposal of a causal connection from automaticity with sublexical units to the rate of reading words containing those units.

There is also evidence of this association between automaticity with sublexical sound-spelling mappings and reading fluency in English. Letter sound fluency measures have been found to be uniquely related to text reading fluency in beginning readers (e.g., Speece & Ritchey, 2005; see also, Ritchey & Speece, 2006; Stage, Sheppard, Davidson, & Browning, 2001). Furthermore, fluency of reading rime-phonograms (e.g., ad, ut, and eep) predicted pseudoword reading efficiency, which in turn accounted for unique variance in text reading fluency in a sample of second-grade readers (R. F. Hudson et al., 2012). A short training study aimed at testing this causal connection found mixed results concerning improved rate for reading words with versus without trained sublexical mappings for first- and second-grade students (Conrad & Levy, 2011). Adding a timing component to accuracy training for sublexical units did increase decoding automaticity for second-grade students, but this advantage did not generalize to text reading fluency (R. F. Hudson, Isakson, Richman, Lane, & Arriaza-Allen, 2011).

Multicomponent, intensive reading interventions have increased fluency outcomes for students with accuracy-defined reading disabilities in English (for review, see Wolf & Katzir-Cohen, 2001; Torgesen & Hudson, 2006). Although not typically analysed separately, these interventions include instruction in dimensions of sublexical learning, such as teaching the most frequent onsets, rimes, and morphological units (e.g., Lovett et al., 2000; Wolf et al., 2009). O'Brien et al. (2011) did find that mid-program visual-search speed for sublexical patterns (e.g., BR, SH, and CK) predicted outcomes of text-reading fluency, but not word reading rate. They concluded that the results "… indicate partial support for the contribution of sublexical orthographic recognition efficiency to reading fluency" (p. 126). Thus, while garnering some support, further research is needed concerning the potential role of sublexical learning to fluency outcomes within a remedial reading program, and for readers with fluency-defined disabilities.

Studies of multicomponent reading interventions in English have not typically included students with accurate but dysfluent reading; however, one report highlights the prevalence of these readers. Of almost 200 adolescent students with comprehension difficulties, 29% were categorized as "dysfluent readers"; that is, with average word reading accuracy and below-average oral reading fluency (Brasseur-Hock et al., 2011). Brasseur-Hock and colleagues explicitly state that different interventions will be needed for these dysfluent readers than for readers with moderate to severe deficits in word reading accuracy; however, this assumption may not be supported. Indeed, there are reasons to suggest that similar interventions may be effective for readers with fluency-defined and accuracy-defined reading disabilities. As previously noted, there have been theoretical and empirical links between single word reading efficiency, sublexical automaticity, and reading fluency in both transparent orthographies and in English (e.g., Hintikka et al., 2008; Ritchey & Speece, 2006). From both a theoretical (R. F. Hudson et al., 2008, 2012) and empirical perspective, it may be that a decoding-focused program is just what is needed for students with fluency-defined reading disabilities.

1.1 | The current study

The first goal of this study is to examine the effects of a program focused on decoding-related skills on the reading outcomes of a group with accurate word reading alongside fluency deficits. This study examines gains on norm-referenced measures as indicators of closing the achievement gap in fluency and reading comprehension (Torgesen et al., 2001). We compared this group's improvement on word- and text-level reading outcomes with a group of readers who had impairments in word reading accuracy and fluency. If connected text reading and repeated readings are critical to improvement for readers with fluency-defined deficits (e.g., A. Hudson et al., 2020), then we would expect an interaction between treatment and group, with educationally meaningful gains only for the group with accuracy-defined reading disabilities. On the other hand, there is an empirical case for a strong association from sublexical and word-reading speed to text-reading fluency (e.g., R. F. Hudson et al., 2012), and from a developmental perspective, deficits for fluency-defined reading disabilities may be similar but occur at a later point in word reading acquisition (Lovett et al., 1988). We hypothesized that readers with fluency-defined disabilities would improve on both word- and text-level reading measures, reducing or eliminating their achievement gap in reading fluency and comprehension.

The second goal of this study is to test whether measures of speeded sublexical learning contribute to gains in reading fluency for students with reading impairments. There is an association between reading sublexical orthographic patterns and reading fluency in correlational studies (e.g., Hudson et al., 2012; Ritchey & Speece, 2006). Previous studies training sublexical pattern recognition have, for the most part, not found effects on generalized fluency outcomes (cf. Fraga González et al., 2015); however, these have mostly been short-term, and the number of sublexical patterns trained limited (e.g., Conrad & Levy, 2011; Hintikka et al., 2008). In the context of a longer-term intervention, with many sublexical patterns introduced throughout, we predicted that individual differences in mastering the speeded sublexical patterns would be associated with gains on a standardized test of reading fluency. Furthermore, we expected this association to occur across all our participants with reading impairments. Finally, we also examined whether fluency outcomes were uniquely related to gains in reading comprehension across participants with both accuracy- and fluency-defined disabilities, thus examining a basic assumption of this research.

2 | METHOD

2.1 | Participants

Participants were selected retrospectively from data collected at a private reading clinic as part of a study on reading disabilities Metsala & David, 2017 85$M = 100$ and $SD = 15$). The criteria for the fluency-defined group were a word reading score above the 25th percentile, and a fluency score at or below the 16th percentile (standard score of 7 or below on measure, $M = 10$ and $SD = 3$). This resulted in a group of 68 participants with accuracy-defined disabilities and 65 with fluency-defined disabilities (see Table 1 for sex, mean age, and mean word reading accuracy and fluency scores).

For the regression analyses, we set the criterion for membership in the accuracy-defined group more liberally – a word reading score below the 25th percentile. This included a larger sample that was the representation of students in the intervention, is consistent with some past research (e.g., Stanovich & Siegel, 1994), and with the finding that reading skills associated with a diagnosis of dyslexia are normally distributed (Parrila & Protopapas, 2017). The accuracy-defined group for all regression analyses consisted of 95 participants (62 males; see Table 1 for mean age, word accuracy, and fluency scores). As can be seen from Table 1, the accuracy-defined groups had severe deficits in fluent text reading – the typical pattern reported for these readers (Torgesen & Hudson, 2006). Participants were mostly from middle or above SES backgrounds, as the intervention is associated with significant fees.

TABLE 1 Descriptive statistics for groups of accuracy-defined and fluency-defined participants

	Comparison groups for ANOVAs				Expanded group for regressions	
	Accuracy-defined ($N = 68$; 44 males)		Fluency-defined ($N = 65$; 41 males)		Accuracy-defined ($N = 95$; 62 males)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Age (months)	125.03	30.87	96.11	23.07	122.35	28.95
SS: Word Reading	78.15	6.09	98.69	7.41	80.68	7.37
SS: Fluency	2.99	1.67	5.63	.945	3.45	1.80

Note: SS, standard score. For the word reading scale, standard scores have an $M = 100$, and an $SD = 15$. For the Fluency scale, standard scores have an $M = 10$, and an $SD = 3$.

2.2 | Reading intervention

The intervention examined in this study was the SpellRead™ (2012) program. The complete program is 120 hr in length, and there are assessments after each phase of the program (i.e., following 45, 90, and 120 hr). The program was delivered by trained paraprofessionals in the clinic to groups of 3–5 students, in two 1.5-hr meetings per week. The instructors deliver the scripted, standardized program. For the first 35–40 min of each hour, participants engage in quick-paced, game-like activities, targeting phonological awareness, grapheme-phoneme correspondences, and decoding. The next 16 min consist of round-robin reading with a book at a suitable level that includes a 3–4-min discussion, and about 6 min of free writing.

The program's delivery occurs in three phases, with all participants starting at the first lesson of Phase 1 and progressing through each lesson. Phase 1 teaches grapheme-phoneme associations and decoding, with instructional activities focused on CVC pseudowords. In Phase 2, both real and pseudowords are used and include reading two-syllable words, with students learning all vowel digraphs. Phase 3 activities, primarily with real words, teaches syllabication, and common orthographic units such as morphemes. The aim for each learning activity is initially accuracy, and then turns to quick, automatic performance.

Students progress through a series of nine-card packs (CPs), each containing a set of sublexical spelling patterns, and move on as time and accuracy criteria are met. Each set of patterns presents a number of short and long vowels and/or vowel digraphs. Vowel spellings are presented first in CV and VC patterns, and then in CVC patterns. For example, for the pattern of a long *a* sound with the silent e, the student might see *ta_e* and *_ane* in the CV/VC CP and then *mape* in the CVC CP. Consonant digraphs are similarly presented in CV and VC patterns (e.g., _esh; cha_e). The CV/VC CPs contain 40 cards and the CVC packs have 50 cards. Two of the nine-CPs provide a review of all previously learned spelling patterns. Students are encouraged to engage in speeded practice with their current card park each night at home. Instructors test students at weekly intervals, recording the time taken and the number of errors.

2.3 | Reading outcome measures

2.3.1 | Word reading accuracy

Word reading accuracy was measured using the Word Identification subtest of the *Woodcock Reading Mastery Tests-Revised* (WRMT-R; Woodcock, 1987). Individual words of increasing difficulty are read until a ceiling of six incorrect.

2.3.2 | Pseudoword reading accuracy

This was measured using the Word Attack subtest of the WRMT-R. Individual pseudowords of increasing difficulty are read until a ceiling of six incorrect.

2.3.3 | Oral reading fluency and reading comprehension

The Gray Oral Reading Test-4 (GORT-4; Wiederholt & Bryant, 2001) was used to measure oral reading fluency and reading comprehension. This test requires the child to read aloud a series of stories of increasing difficulty. After each story, the student answers five multiple-choice questions.

The fluency standard score is a composite across all stories read and considers the time taken and the number of errors. The test is discontinued when the participant's recorded time and accuracy meet a specified criterion.

The comprehension standard score is based on the total number of questions answered correctly. The comprehension component is discontinued when a student answers three of five questions incorrectly for a given story.

2.4 | Speeded sublexical pattern recognition

The students completed a timed test each week with their current CP. Criteria for mastering a CP and moving onto the next were a time of 60 s or less with no more than two errors. There were 40 participants who each took 5 weeks to master both of the first two CPs; Cronbach's alpha for time recorded was .82 across these 10 weeks. For the entire sample that took at least 2 weeks for CP 1, and 3 weeks for CP 2, reliability was .83 across these 5 weeks. We computed two variables across the first two CPs to measure speed and mastery with these sublexical patterns.

2.4.1 | Weeks to mastery

The first measure was the average number of weeks taken for the participant to reach the criteria of 60 s with no more than two errors. If the participant did not reach these criteria for a given CP in the first 5 weeks, a score of 6 weeks was assigned (data less complete after 5 weeks).

2.4.2 | Sublexical fastest time

The second measure captured how quickly a participant got with the CPs. To compute this measure, the fastest time attained for each of these first two CPs was averaged.

2.5 | Procedure

Participants were tested individually, in a quiet room in the reading clinic. Alternate forms of tests were used for each subsequent testing session and the assessor was not the student's intervention instructor. Neither this research nor the research team benefitted monetarily from this study, and there were no conflicts of interest. Previous research by Torgesen's team examining SpellRead™ (e.g., Rashotte et al., 2001) motivated our investigation of these research questions in the context of this program.

Not all participants continue after each phase of the program. Parents' most frequent reasons for discontinuing are that their goals for their child have been met, or time or money demands were too taxing. As noted, there were 68 accuracy-defined and 65 fluency-defined participants for group comparisons in Phase 1, and this was reduced to 43 and 42 for Phase 2, and 28 and 30 for Phase 3, respectively. Figure 1 presents a timeline showing the phases of the intervention and the four testing points.

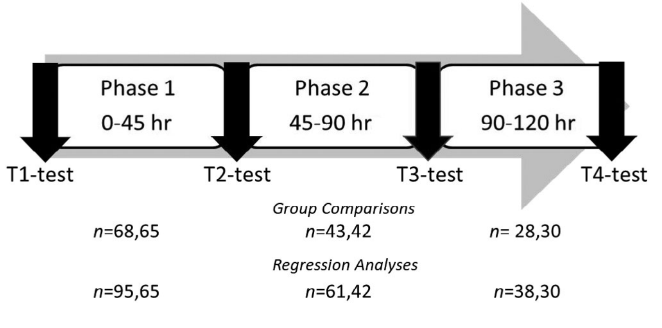

FIGURE 1 Timeline of testing sessions and intervention phases, and associated *n*s

A MANOVA showed that those who did not continue onto the second phase of the program ($n = 48$) were overall stronger readers than those who remained ($n = 85$), $F(4,127) = 3.02$, *Wilks's* $\Lambda = .913$, $p = .020$; univariate tests were significant for pseudoword reading (103.21 vs. 99.19; $F[1,130] = 4.17$, $p = .043$) and fluency (6.23 vs. 5.00; $F(4,127) = 5.89$, $p = .017$); but not for word reading (96.67 vs. 92.78; $F(4,127) = 3.12$, $p = .080$), or comprehension (8.44 vs. 8.29; $F(4,127) = .088$, $p = .767$). Interestingly, these two groups did not differ on any of their pre-treatment reading scores (*ps* = .299–.805). A MANOVA examining these four outcomes for those who did not continue onto Phase 3 ($n = 26$) versus those who did ($n = 57$) was not significant, $F(4,78) = 2.05$, *Wilks's* $\Lambda = .905$, $p = .096$, as were none of the univariate tests (*p*'s = .188 to .392).

3 | RESULTS

Standard score distributions were normal. Missing data points (<1.5%) were not replaced for group comparisons. Split Plot ANOVAs were used to examine outcomes on each reading measure, across each intervention phase. Congruent with our research questions, only the effects of time and the interaction of Group × Time were examined. If assumptions for an ANOVA were violated, each group's increases on that measure were examined with pairwise *t* tests. We used the Benjamini-Hochberg procedure to control for type 1 errors (Benjamini & Hochberg, 1995). With the False Discovery Rate set at 2% of the significant findings for these 24 comparisons, the criterion for statistical significance was $p < .014$. For posthoc tests, a Bonferroni correction was applied (criterion, $p < .012$).

3.1 | Word-level reading accuracy outcomes

For Phase 1 of the program, standardized word reading accuracy scores were submitted to a 2 Group (accuracy-defined; fluency-defined) × 2 Time (0 hr, post-45 hr) Split Plot ANOVA (see Table 2 for all *F*-, *p*-, and η_p^2- values for all ANOVAs). There were significant effects of Time and a Group × Time interaction. Pairwise comparisons revealed that both groups improved, but the gains were larger for the accuracy-defined group, *M diff* = 7.75, $p < .000$, *Cohen's d* = 1.039, than for the fluency-defined group, *M diff* = 4.15, $p < .000$, *Cohen's d* = .499 (see Figure 2).

A similar ANOVA was conducted for Phase 2, with Group and Time (post-45 hr, post-90 hr). The main effect of Time and the interaction were significant. Pairwise comparisons showed that the accuracy-defined group made significant gains over this phase, *M diff* = 4.98, $p < .000$, *Cohen's d* = .580; the fluency-defined group did not, *M diff* = 1.19, $p = .265$, *Cohen's d* = .125.

An ANOVA on word reading standard scores across Phase 3 violated the assumption of the equality of error variances (*Levene statistic* < .05). Paired samples *t* tests were therefore used to examine each group's performance on word reading from post-90 hr to post-120 hr. The accuracy-defined group made significant gains, $t(27) = 5.68$, $p = .000$, *M diff* = 5.07, *Cohen's d* = .718; the fluency-defined group's improvement was not significant at $p < .014$; $t(29) = 2.25$, $p = .032$, *M diff* = 2.10, *Cohen's d* = .185.

The same three Split Plot ANOVAs were conducted to examine gains on pseudoword reading accuracy standard scores. For each phase, only the main effect of Time was significant. Participants improved on their pseudoword reading across each phase of the program (see Figure 2), and these gains were associated with large effect sizes (see Table 2).

3.2 | Text-level reading outcomes

To examine gains in reading fluency across each phase of the intervention, the same Split Plot ANOVAs were completed (see Table 2). While an interaction was present for Phase 1, $F(1,131) = 8.64$, $p = .001$, T1 fluency scores for

TABLE 2 Group ANOVAs for each phase of the reading intervention

	Phase 1			Phase 2			Phase 3		
	F	*p*	η_p^2	*F*	*p*	η_p^2	*F*	*p*	η_p^2
Word reading	*ns* = 68/65; *df* (1,131)			*ns* = 43/42; *df* (1, 83)			*ns* = 28/30*		
Time	120.79	.000	**.480**	17.13	.000	**.171**			
Group × Time	11.02	.001	**.078**	6.46	.013	**.072**			
Pseudoword reading	*ns* = 68/65; *df* (1,131)			*ns* = 43/42; *df* (1, 102)			*ns* = 28/30; *df* (1, 66)		
Time	266.11	.000	**.670**	68.56	.000	**.452**	87.50	.000	**.610**
Group × Time	.011	.918	.000	1.45	.231	.017	1.72	.195	.030
Fluency	*ns* = 68/64*			*ns* = 42/41; *df* (1, 100)			*ns* = 28/29; *df* (1, 65)		
Time				53.24	.000	**.397**	27.73	.000	**.335**
Group × Time				1.54	.218	.019	.001	.994	.000
Reading comprehension	*ns* = 68/64; *df* (1, 130)			*ns* = 42/41*			*ns* = 28/29*		
Time	29.31	.000	**.184**						
Group × Time	1.62	.205	.012						

Note: *ns*, number of participants with accuracy-defined disabilities/number of participants with fluency-defined disabilities. Bolded text indicates effect sizes associated with significant *F* statistics.
*Assumptions of ANOVAs violated; comparisons reported in the results section.

the accuracy-defined group were associated with larger error variance than for the fluency-defined group (*Levene statistic* < .05). Paired samples *t*-tests were thus used, and showed that the accuracy-defined group made gains in fluency, $t(67) = 3.213$, $p = .002$, *M diff* = .662, *Cohen's d* = .352, as did the fluency-defined group $t(65) = 5.904$, *M diff* = 1.692, $p = .000$, *Cohen's d* = .992. The effect size for the fluency-defined group was almost three times that of the accuracy-defined group (see Figure 3).

The ANOVAs for fluency scores across Phase 2 and 3 showed only the main effects of Time. Participants standardized fluency scores improved significantly across Phase 2 and Phase 3 of the intervention, and these gains were associated with large effect sizes (see Figure 3).

For the ANOVA examining Phase 1 reading comprehension, there was a main effect of Time. Across the first 45 hr of the program, participants made gains in reading comprehension, associated with a large effect size (see Table 2 & Figure 3).

For each of Phase 2 and 3 of the intervention, the assumption of equal error variances was violated (*Levene statistic* < .05). Paired samples *t*-tests were therefore used to examine each group's performance across each phase. Across Phase 2, the accuracy-defined group made significant gains in reading comprehension, $t(41) = 4.71$, $p = .000$, *M diff* = 1.810, *Cohen's d* = .795, but the fluency-defined group did not, $t(40) = 1.48$, $p = .146$, *M diff* = .75, *Cohen's d* = .276. In contrast, across the last phase of the program, the accuracy-defined group did not improve, $t(27) = 1.29$, $p = .210$, *M diff* = .393, *Cohen's d* = .228, but the fluency-defined group did make gains, $t(28) = 5.444$, $p = .000$, *M-diff* = 1.69, *Cohen's d* = .697 (see Figure 3).

3.3 | Contributions of sublexical automaticity to gains in reading fluency

Increasing standardized fluency scores in students with reading disabilities have proven difficult (Torgesen & Hudson, 2006). To test the association between sublexical automaticity and reading fluency in the context of this intervention, we next examine if students' performance on mastering the sublexical spelling patterns predict unique variance in fluency outcomes (see Table 3 for zero-order correlations). In a series of regressions, age, pre-test fluency, pre-test word reading, and group membership were accounted for, before entering the sublexical fluency

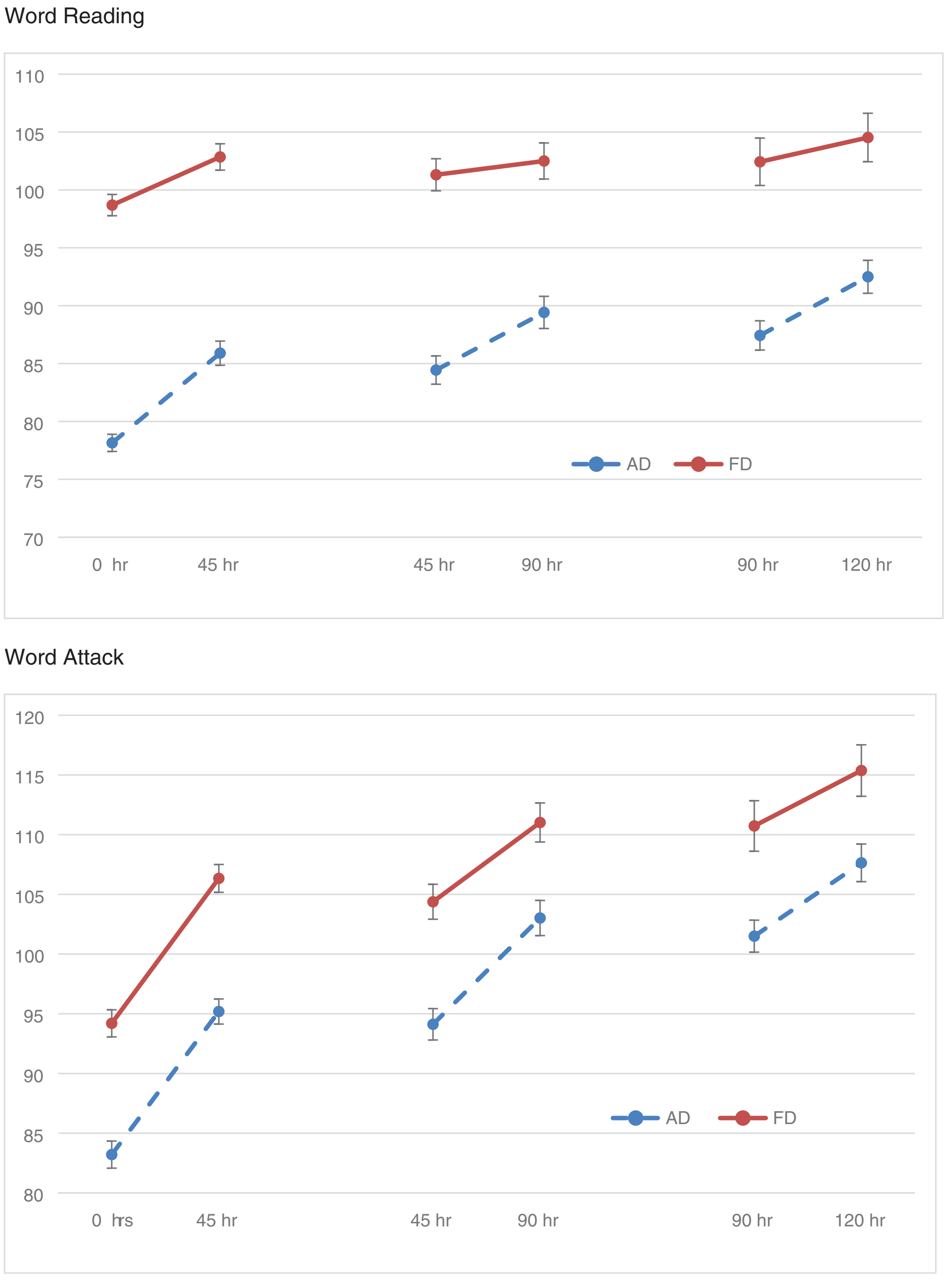

FIGURE 2 Mean word reading (top) and pseudoword reading (bottom) standard scores for each comparison time point in the ANOVAs. Error bars represent *SEM* [Colour figure can be viewed at wileyonlinelibrary.com]

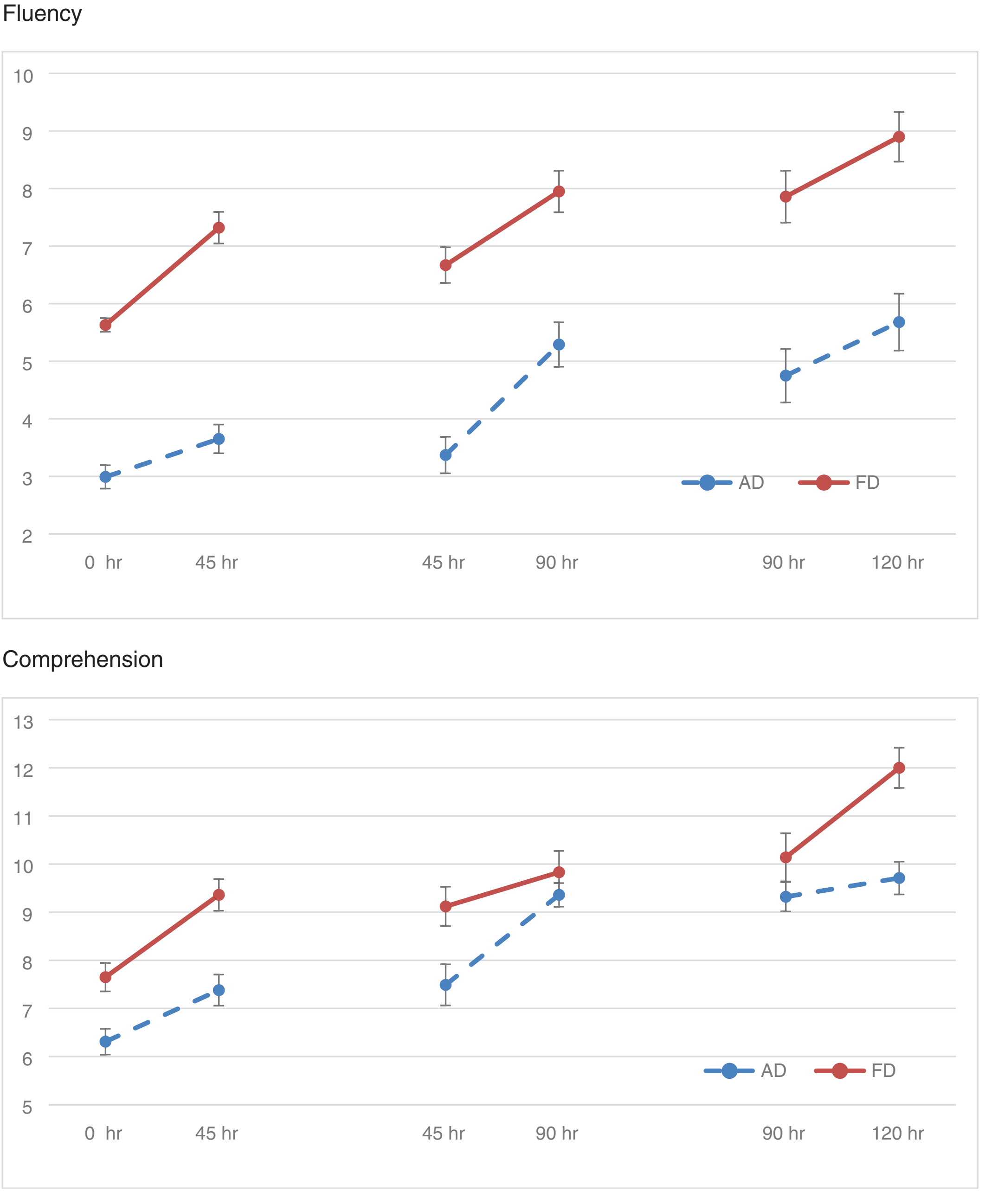

FIGURE 3 Mean fluency (top) and reading comprehension (bottom) standard scores for each comparison time point in the ANOVAs. Error bars represent *SEM* [Colour figure can be viewed at wileyonlinelibrary.com]

measure. These regressions were carried out on the complete sample. Outcomes for Phase 1 had 160 participants (95 accuracy-defined and 65 fluency-defined), for Phase 2 there were 102 participants (61 and 42, respectively), and for Phase 3 there were 68 participants (38 and 30, respectively).

Predicting fluency outcomes after 45 hr of instruction, Step 1 accounted for 53.4% of the variance (see Table 4). Group was not a significant predictor in Step 2. As Step 3, Average weeks to mastery predicted 2.8% of the additional variance. When entered as Step 3 in a separate regression, fastest time predicted 2.4% additional variance in reading fluency.

TABLE 3 Correlations for major variables in regression analyses predicting fluency

	1.	2.	3.	4.	5.	6.
1. Word Rdg (pre-test)	—					
2. Fluency (pre-test)[a]	.674**	—				
3. Fluency (45 hr)[a]	.634**	.652**	—			
4. Fluency (90 hr)[b]	.564**	.597**	.689**	—		
5. Fluency (120 hr)[c]	.573**	.649**	.655**	.880**	—	
6. Weeks to mastery	.145	−.066	−.218**	−.197*	−.334**	—
7. Fastest time	.195*	−.017	−.164*	−.188	−.271*	.784**

**$p \le .01$; *$p < .05$. [a]$N = 160$.
[b]$N = 103$.
[c]$N = 68$.

TABLE 4 Hierarchical regressions predicting fluency standard scores following each phase of the intervention

	Phase 1		Phase 2		Phase 3	
Step/predictor	ΔR^2	**Final β**	ΔR^2	**Final β**	ΔR^2	**Final β**
1. Age	.534**	.085	.400**	−.138	.456**	−.241
Pre-test fluency		.310**		.376**		.426**
Pre-test word reading		.400**		.396**		.216
2. Group	.007	.140	.024*	−.212	.008	−.146
Regression 1						
3. Weeks to mastery	.028**	−.221**	.037**	−.252**	.069**	−.374**
Regression 2						
3. Fastest time	.024**	−.189**	.059*	−.294*	.049*	−.277*

**$p < .01$; *$p = .05$.

The same hierarchical regressions were carried out on standardized fluency measures following 90 hr of the intervention. As seen in Table 4, Step 1 accounted for 40% of the variance. Group accounted for an additional 2.4% of the variance as Step 2. At Step 3, weeks to mastery accounted for an additional 3.7% of the variance. In a separate regression, the fastest time accounted for an additional 5.9% of the variance in Phase 2 fluency outcomes.

For fluency outcomes following the complete program, Step 1 accounted for 45.6% of the variance, and Group was not significant in Step 2. Weeks to mastery accounted for an additional 6.9% of the variance in fluency outcomes. In a separate regression, the Fastest Time accounted for an additional 4.9% of the variance in fluency outcomes.

Thus, speeded learning of the sublexical patterns was associated with fluency outcomes following each phase of the intervention. A group × sublexical learning interaction term did not account for additional variance when entered as Step 4 into the above-reported analyses. Thus, the association between sublexical performance and fluency outcomes was consistent across both groups.

3.4 | Predicting gains in reading comprehension

Our final analyses examined the unique association between outcomes in fluency and readers' gains in reading comprehension. Step 1 in the regression for each phase was the comprehension score at the beginning of that phase.

TABLE 5 Hierarchical regressions predicting comprehension standard scores across each intervention phase

	Phase 1		Phase 2		Phase 3	
Step/predictor	ΔR^2	Final β	ΔR^2	Final β	ΔR^2	Final β
1. Beginning Rdg comp	.101**	.123	.089**	.026	.272**	.276**
2. Word reading	.166**	.173*	.123**	−.020	.165**	.225*
3. Fluency	.281**	.815**	.214**	.655**	.049**	.337**

**$p < .01$; *$p = .05$.

Steps 2 and 3 were the word reading and fluency scores at the end of that phase, respectively (see Table 5). For Phase 1, T2 fluency accounted for 28.1% of the unique variance in T2 reading comprehension outcomes. For Phase 2, T3 fluency accounted for an additional 21.4% of the variance in T3 reading comprehension and was the only significant predictor in the final equation accounting for 42.6% of the total variance. In the last hierarchical regression, T4 fluency accounted for an additional 4.9% of the variance in T4 reading comprehension.

4 | DISCUSSION

Research on English-language readers with accurate word reading alongside deficits in reading fluency is somewhat scarce. This study sought to contribute to this limited literature base, as these students may be prevalent among readers with comprehension difficulties (e.g., Brasseur-Hock et al., 2011; Moats & Tolman, 2009). Overall, this program targeting word-reading-related skills appeared effective for readers with fluency-defined disabilities. Significant gains were made in fluency for each phase of the program, and reading comprehension difficulties were fully remediated for this group of readers. We also found that learning for speeded recognition of sublexical spelling patterns predicted gains in reading fluency following each phase of the intervention. We next elaborate on each finding and discuss practical and theoretical implications.

4.1 | Effects of the word and sublexical focused remedial reading intervention

The SpellRead™ (2012) program appeared to have significant and educationally meaningful effects on impaired text-level outcomes for readers with fluency-defined reading disabilities. There was a large boost to this group's fluency across the initial phase of the intervention (*Cohen's* $d = .99$). We suggest this large increase in reading fluency resulted in the simultaneous gains observed in reading comprehension, a suggestion supported by the unique association we found between fluency outcomes and gains in reading comprehension. Indeed, this groups' mean reading comprehension score came into the solidly average range following these first 45 hr. Standard fluency scores continued to increase across the program with a mean standard fluency score about average following 90 hr, and more solidly average upon completion of the program. That this word-focused intervention effectively closed the reading achievement gap for these fluency-defined readers conflicts with proposals that a different type of intervention, focused on reading beyond the word level, is needed for these readers (e.g., National Reading Panel, 2000; Pikulski & Chard, 2005).

Students with fluency-defined and accuracy-defined reading disabilities had similar gains for most of the word- and text-level reading outcomes. One exception followed the first phase of the program, when the accuracy-defined group made larger gains in word reading, whereas the fluency-defined group made greater gains in fluency. The same instructional content and strategies (i.e., foci on grapheme-phoneme knowledge, reading single/CVC/syllables, and speeded practice with sublexical spelling patterns), appeared to target the primary deficit for each group in this initial phase of the program. These findings support the notion that the breakdown for these accurate but dysfluent English readers is in the word-reading module, but at a later point of the acquisition process than in accuracy-defined disabilities (Lovett et al., 1988) – a proposal consistent with studies of dyslexia in transparent orthographies (e.g., Moll et al., 2020). Students with accuracy-defined reading disabilities have difficulty learning grapheme-phoneme correspondences and reliably using these to decode words accurately, the earliest phase of reading acquisition (Ehri, 2014). The breakdown for fluency-defined readers may be relatively later when word reading becomes increasingly consolidated and automatic (Ehri, 2014). Deficits in the integration (or "fusing") of grapheme-phoneme units, related to the development of specialized neural circuits, may be the cause of the early fluency deficits associated with dyslexia (Blomert, 2011). This difficulty may impede further fluency development, which depends on quick recognition of higher-level orthographic patterns (e.g., Berninger et al., 2006).

The findings of educationally meaningful increases in word- and text-level reading outcomes for the fluency-defined group lend support to theories of fluent reading development that emphasize word and sublexical recognition processes as the drivers of fluent reading and its development (e.g., R. F. Hudson et al., 2008, 2012). Furthermore, fluency scores were uniquely predictive of gains in reading comprehension across all participants and all phases of the intervention. Once fluency scores increased from this decoding-focused program, reading comprehension scores also increased for readers with fluency-defined reading disabilities. Connected text reading and rereading, often purported to be critical for dysfluent readers (e.g., Chard et al., 2009; O'Keeffe et al., 2012), may not be the active ingredient in programs that increase fluency and comprehension outcomes. Direct comparisons of connected text versus word-reading focused remedial programs are needed to better understand potential differential effects. The efficacy of the multicomponent program examined in this study, largely targeting skills related to word and sublexical reading accuracy and speed, does bring into question demands for interventions with a more exclusive focus on connected text-reading for students with impairments in fluency (e.g., Chard et al., 2002, 2009; Wu, Stratton, & Gadke, 2020; Zimmermann, Reed, & Aloe, 2019), with or without accuracy deficits.

4.2 | Contributions of sublexical automaticity to reading fluency

Individual differences in learning the rapid recognition of sublexical sound-spelling mappings contributed to impaired readers' gains in reading fluency. Participants who took fewer weeks to meet the criterion time for reading the patterns, and those who learned to read the patterns more quickly, made greater gains on reading fluency. Variance accounted for by beginning fluency scores, also a speeded measure were controlled, and therefore the observed association is not due solely to this shared timing component. Our findings are perhaps most closely related to the large effects observed on word reading fluency for a group of accurate but dysfluent readers, following extensive training in building automaticity with increasingly complex Dutch letter-sound associations (Fraga González et al., 2015). Our findings thus add to a growing body of research that supports a link between sublexical automaticity and reading fluency (Hintikka et al., 2008; R. F. Hudson et al., 2012). We extend this previous work insofar as the association was found for a standardized measure of text reading fluency and for readers with both accuracy- and fluency-defined reading disabilities.

The contributions of sublexical automaticity to generalized text reading fluency suggest that the approach to sublexical training in the SpellRead™ (2012) program may warrant further study. The practice with the sublexical patterns is speeded and continues until both accuracy and speed criteria are met; consistent with findings that speeded practice with word-parts increased the efficacy of training with young children (R. F. Hudson et al., 2011). Furthermore, the patterns introduced are varied in word position and there are many patterns practiced until mastery throughout the program. This contrasts with shorter-term training studies finding limited generalization, which have frequently focused on spellings in one position (e.g., onset clusters), of a given length (e.g., bigrams), and do not include the extensive number of patterns or speeded practice to mastery employed in the SpellRead™ program. Sublexical training, as carried out in this program, may enhance fluency remediation for readers with accuracy-defined and fluency-defined reading disabilities. The other components of the SpellRead™ program will also have contributed to gains in word reading accuracy and fluency. Additional research is needed to further isolate the specific effects of the speeded practice with sublexical spelling patterns.

4.3 | Limitations and conclusion

The findings from the current study are consistent with theoretical and empirical examinations of word reading accuracy and fluency acquisition (e.g., Ehri, 2014; R. F. Hudson et al., 2008, 2012); however, our conclusions must be considered within the limitations of this study. The attrition of the sample after each subsequent phase of the intervention limited our data analytic strategy. Furthermore, the group of readers who continued onto Phase 2 were weaker readers than those who discontinued. In real-life interventions, participants may quit an intervention once their goals are perceived to have been met. Perhaps the most significant limitation is that there was not a comparison group, as no students are wait-listed at the private clinic. Caution is therefore needed concerning all our causal arguments, including attributing the reading improvements we observed to the intervention. Even so, our school-age participants had longstanding difficulties which were not previously remedied with time or schooling alone. Rather, standard score gains for students with reading disabilities are most often hard-won (Torgesen & Hudson, 2006), and standardized fluency scores are particularly difficult to improve even with intensive reading interventions (Norton & Wolf, 2012; Torgesen & Hudson, 2006). For example, over a period of about 23 weeks, a wait-listed comparison group with average word reading accuracy but serious fluency deficits, did not make gains in standardized scores of text-reading fluency or word reading rate (Fraga González et al., 2015). Nevertheless, research including a no-treatment or alternate treatment comparison group is needed to validate our findings. Furthermore, including participants across a wider range of socio-economic backgrounds will also support generalizations of the findings.

The current study suggests that multicomponent reading interventions, primarily targeting word reading-related skills and automaticity with these, will be beneficial for students with accurate word reading coupled with fluency impairments. We suggest that the components involved in the sublexical training in the SpellRead™ program may be instrumental in achieving this end. After only one phase of the reading program, fluency and comprehension had significant standard score boosts for these dysfluent readers and they continued to improve in later phases of the program. Performance on sublexical measures accounted for unique variance in gains in reading fluency across all our impaired readers. We suggest that further examinations on the specific links between comprehensive sublexical automaticity training and fluency outcomes will help to increase our understanding of fluency development and of the most effective remediations for dysfluent readers.

ACKNOWLEDGMENT

This research was supported by the Gail and Stephen Jarislowsky Learning Disabilities Research Endowment to Mount Saint Vincent University. We thank the teaching staff and student participants for their contribution to this research.

DATA AVAILABILITY STATEMENT

Research data are not shared.

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How to cite this article: Metsala, J. L., & David, M. D. (2021). Improving English reading fluency and comprehension for children with reading fluency disabilities. *Dyslexia*, 1–18. https://doi.org/10.1002/dys.1695