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A meta-analysis of morphological interventions: effects on literacy achievement of children with literacy difficulties

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Abstract This study synthesizes 79 standardized mean-change differences between control and treatment groups from 17 independent studies, investigating the effect of morphological interventions on literacy outcomes for students with literacy difficulties. Average total sample size ranged from 15 to 261 from a wide range of grade levels. Overall, morphological instruction showed a significant improvement on literacy achievement ($\overline{d}$=0.33). Specifically, its effect was significant on several literacy outcomes such as phonological awareness ($\overline{d}$=0.49), morphological awareness ($\overline{d}$=0.40), vocabulary ($\overline{d}$=0.40), reading comprehension ($\overline{d}$=0.24), and spelling ($\overline{d}$=0.20). Morphological instruction was particularly effective for children with reading, learning, or speech and language disabilities, English language learners, and struggling readers, suggesting the possibility that morphological instruction can remediate phonological processing challenges. Other moderators were also explored to explain differences in morphological intervention effects. These findings suggest students with literacy difficulties would benefit from morphological instruction.

Keywords Learning disabilities · Literacy achievement · Morphological intervention · Reading disabilities · Reading instruction

Recently, there has been an increasing concern about low levels of literacy achievement among children and adolescents (Deshler & Hock, 2007). According to the most recent National Assessment of Educational Progress (NAEP) data released in 2007, 34% of fourth grade public school students have been classified as reading below the basic reading level

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(Lee, Grigg, & Donahue, 2007). The percentage is even worse for children with learning disabilities (LD). Thus, improving literacy achievement for these children has been a primary concern for both educators and researchers.

Much of the current research focuses on the role of phonological instruction in improving literacy achievement, yet this present study explores a different option. Because English is morpho-phonemic, which means that English uses both units of meaning termed *morphemes* and units of sound called *phonemes* to create and adjust meaning and spelling within words, it makes sense that morphological instruction may improve literacy achievement (Chomsky & Halle, 1968; Reed 2008). Since researchers have found evidence of children with dyslexia using morphology as a compensatory strategy in reading (Casalis, Cole, & Sopo, 2004; Elbro & Arnbak, 1996), it is important to explore morphological interventions as a means to improve literacy achievement for children with learning/reading disabilities, struggling readers, and poor spellers.

Although morphological awareness correlates more highly than phonological or syntactic awareness with spelling and reading (Siegel 2008), it has received less attention by researchers and educators (Abbott & Berninger, 1999; Henry 2003; Hurry et al. 2005; Nunes, Bryant, Pretzlik, & Hurry, 2006). For example, morphological instruction was not examined in the comprehensive review by the National Reading Panel published in 2000 (National Institute of Child Health and Human Development 2000). With an increased interest in morphological instruction, two syntheses examining morphological instruction were published in last 2 years. However, they summarized study findings in more of a narrative rather than statistical manner.

One recent synthesis by Reed (2008) reviewed seven published studies involving morphological instruction and examined the effect of morphological instruction on three reading outcomes including word identification, spelling, and vocabulary development. Her synthesis was a narrative description of effect sizes and she did not perform quantitative analyses that compare the intervention effects on reading outcomes. The other most recent review by Bowers, Kirby, and Deacon (2010) obtained simple averages of effect sizes and standard deviations from 22 published studies of morphological interventions in multiple languages, showing that morphological interventions showed positive means on sublexical, lexical, and supra-lexical literacy achievement. However, the overall estimate in their study was not based on a variance-weighted estimate, which is considered as a proper way to synthesize effect-sizes having different sample size (described in Cooper, Hedges, & Valentine, 2009), and did not perform statistical comparisons of study findings by type of literacy achievement (i.e., sublexical, lexical, and supra-lexical literacy achievement).

Using the quantitative meta-analytic technique (Cooper, Hedges, & Valentine, 2009; Glass 1976; Gleser & Olkin, 1994), our meta-analysis based on 17 independent studies examines how morphological interventions affect literacy outcomes, with a special focus on children who tend to struggle with literacy achievement. In particular, we first compute the overall mean effect of morphological intervention on literacy achievement, and further compare its effect across several areas of literacy outcomes including reading comprehension, decoding, fluency, morphological awareness, phonological awareness, phonological recoding, spelling, and vocabulary. Such comparison is made based on a moderator analysis that examines differential effects of morphological intervention by literacy outcome. Also, a series of moderator analysis is performed in order to examine differences in intervention effects by other study features such as extent of the intervention, focus of intervention, treatment unit, learner type, and average hours of morphological intervention.

Specifically, the following three main questions are examined:

1. Does morphological instruction improve literacy achievement for children who tend to struggle with literacy achievement?
2. Does morphological instruction improve different areas of literacy achievement such as reading comprehension, decoding, fluency, morphological awareness, phonological awareness, phonological recoding, spelling, and vocabulary knowledge for children who tend to struggle with literacy achievement?
3. Does the effect of morphological instruction on literacy outcomes differ by several study features such as extent of intervention, focus of intervention, and treatment unit?

What is morphological awareness?

Morphological instruction aims to improve morphological awareness, or the "conscious awareness of the morphemic structure of words and their ability to reflect on and manipulate that structure" (Carlisle 1995, p. 194). Such awareness involves the use of morphemes within words at the inflectional (*jump+s or jump+ing; changes tense or number or gender*), derivational (*dis+respect+ful; changes grammatical category or meaning*), or compounding (jump+ball) level. More comprehensive discussion of morphological awareness can be found in Carlisle (2003) and Kuo and Anderson (2006).

Transparency and frequency both affect morphological processing (Carlisle 2003). For example, morphemic units that are used more frequently such as the *teach* in *teacher* are recognized more easily than the *lecture* in *lecturer*. In terms of transparency, some morphological relationships are clearer than others. For example, derivational changes such as *grow* to *growth* change the root word's grammatical category and meaning without changing the pronunciation or spelling of the morphemes, and are therefore transparent. Changes such as *heal* to *health* or *magic* to *magician* involve morphological and phonological changes, which decreases the transparency of the relationship. The most opaque relationship, such as the change from *five* to *fifth,* involves morphological, phonological, and orthographic changes. The less transparent the change, the more difficult it is for students to use morphological awareness to aid decoding and meaning acquisition (Carlisle 2003; 2000; Singson et al. 2000).

This issue of transparency has important implications for the interventions discussed in this study. Because inflectional suffixes and neutral derivational morphemes are easier to recognize, interventions often begin with instruction involving clear morphological relationships that are easier for students to identify, understand, and build with. Next, interventions move towards instruction of more difficult, non-neutral derivational morphemes which involve phonological, orthographic, and morphological processing. This link to phonological and orthographic processing shows how morphological instruction often involves phonological and orthographic support as well.

Why morphological instruction?

Before performing a meta-analysis, theoretical and empirical evidence that morphological instruction may increase literacy achievement for struggling readers and spellers must be discussed. Theoretically, improving morphological awareness has important implications for literacy achievement. For example, pronunciation of words is often based on morphemic

rules, with *dishearten* pronounced as *dis+hearten* rather than *di+shearten* or *dish+earten* because the syllable break is based on the morpheme *dis* and its meaning of *not* (Kuo & Anderson, 2006). Similarly, the pronunciation of *ive* depends on whether it is a derivational suffix as in *suggestive* or *detective* or whether it is part of a monomorphemic word such as *survive* or *arrive* (Kuo & Anderson, 2006). In addition, breaking down complex words into morpheme components allows the reader to decode and access the meaning of larger words. For example, within the larger word *disrespectful* are the base word *respect* and the component morphemes *ful* and *dis.* Readers can use the decoded meaning of *respect* and *ful* and *dis* to gain a sense of the meaning of *disrespectful*. With improved accuracy of word identification and meanings, comprehension improves because the reader has more information with which to make inferences and construct an accurate text model (Perfetti 1988).

Knowledge of the meaning of and how units of meaning relate to grammar and spelling also improve language outcomes. With the deep orthography of English, units of meaning can have identical pronunciations but different orthographies. When this occurs, morphological units can support students in learning and using complex spelling patterns and exceptions. For instance, the word *vineyard* is pronounced *vin+yard*, but spelled *vine+yard* because of its meaning, *a yard full of vines*. In the case of the words *peeled* (two morphemes: *peel+ed*) and *field* (one morpheme), which sound the same but are spelled differently, knowledge of the past tense *ed* morpheme provides students with a reason for the different spellings (Nunes et al. 2006).

Theoretically, improving morphological awareness may have particularly important implications for struggling readers and spellers because morphemes carry meaning while phonemes must be put together to create meaning. "Whereas phonemes distinguish between meaningful elements (e.g., p/b distinguishes *pat* from *bat*), morphemes are themselves meaningful, thereby increasing their salience. Thus, *electric* and *electricity* share a common meaningful unit in a way that *pat* and *bat* do not" (Fowler & Liberman, 1995, p. 161). Perhaps because these units of meaning are easier to access, research has shown that participants can perform more difficult tasks at the syllable or morpheme level than those that they can complete at the phoneme level (Rozin, Poristsky, & Sotsky, 1971).

Although children with reading and language disabilities show less awareness of language features including morphology and therefore perform worse on most morphological tasks compared to readers of their age (Carlisle 1987; Casalis et al. 2004; Fowler & Liberman, 1995; Rubin, Patterson, & Kantor, 1991; Siegel 2008), researchers have found that morphological awareness may support some struggling readers. For example, Elbro and Arnbak (1996) found Danish teenagers with reading problems performed significantly lower on word reading measures, except when reading morphologically transparent words, which they read faster than control students. These same researchers showed that students with dyslexia read more accurately and faster when presented text morpheme-by-morpheme rather than syllable-by-syllable whereas control students showed no such differences. In fact, adolescents with dyslexia read equally well when presented with morphemes as when presented with words, whereas control students read better when reading words.

With that said, children with learning disabilities also have disproportionate difficulties compared to good readers on morphological tasks that require production of answers versus choice or those tasks that are written versus oral (Carlisle 1988; Champion 1997; Windsor & Hwang, 1997) and identifying opaque morphological relationships (Carlisle, Stone, & Katz, 2001; Champion 1997; Windsor 2000), which often involve phonological processing which is a weakness for many struggling readers. As a result, morphological instruction may be particularly important for these students, who have greater difficulty with many

aspects of morphological processing yet have the potential to use this processing as a support. Also, there is some evidence that students with different phonological processing abilities have similar morphological skills, therefore suggesting that morphological awareness could provide additional support to students with phonological deficits (Casalis et al. 2004). For example, Casalis et al. (2004) showed that two different groups of children with dyslexia, those with phonological dyslexia who have phonological deficits and those with delayed dyslexia who follow typical patterns of reading development in a delayed timeframe and therefore do not have phonological deficits, both had similar scores on a morphological task that required students to complete a sentence with a derivation given a base or complete the sentence with the base given a derived form of the word.

Current evidence regarding morphological interventions

In addition to theoretical evidence, several empirical studies have shown that morphological awareness can improve literacy outcomes for students with disabilities and struggling readers and spellers although these interventions have varied greatly in terms of goals, instruction, intensity, duration, group size, sample size, assessment measures, and size of effect (see Table 1). Together, they provide evidence that morphological awareness can be taught, but the large degree of variability suggests the need for a synthesis of these studies. In addition, most studies did not report an effect size resulting in difficulty determining how effective many of the interventions were in improving literacy outcomes. In the review that follows, general findings for each area of literacy will be discussed with some of the seminal works highlighted.

Literacy effects in English

Morphological instruction has been shown to improve decoding for students with reading disabilities (Abbott & Berninger, 1999; Berninger et al. 2008; 2003; Edwards 1982; Henry 1987, 1988; Henry, Calfee, & Avelar-LaSalle, 1989; Lovett et al. 2000; Lovett & Steinbach, 1997) and struggling readers (Carlisle 2007; Katz & Carlisle, 2009; Vadasy, Sanders, & Peyton, 2006). Similarly, interventions with morphological instruction also seem to improve reading comprehension for students with learning disabilities (Carlisle 2007; Katz & Carlisle, 2009; Lovett et al. 2000) and struggling readers (Carlisle 2007; Katz & Carlisle, 2009; Vadasy et al. 2006). Studies have also shown that morphological interventions result in improved spelling achievement for students with reading disabilities (Abbott & Berninger, 1999; Berninger et al. 2008; Henry 1987; Henry et al. 1989; Lovett & Steinbach, 1997) and for students with low achievement in spelling (Robinson & Hesse, 1981). Furthermore, research has also shown that morphological instruction improves vocabulary outcomes for students with learning disabilities (Katz & Carlisle, 2009; Carlisle 2007; Harris 2007) and for low achievers (Carlisle 2007; Katz & Carlisle, 2009; Nunes et al. 2006). Although these studies have shown positive effects on literacy outcomes, effects have varied both within studies across different components of literacy and across studies that have different populations and interventions. In addition, some studies did not find significant group effects, but reported moderate effect sizes or trends towards individual improvement. These large variations in findings suggest both the potential success of morphological instruction and the need to integrate findings across studies.

Table 1 Morphological interventions

Author	Focus	Extent	*N*	Treatment unit	Length of treatment	Grade/age	Type of learner	Treatment strategy	Reading outcome	ES range
Abbott and Berninger (1999)[a]	L	CM	10	Ind	16 weeks; 16 h total; 4h morph	4-7th	RD	D, M, O, P, S	C, D, F, P, PR S	−0.78 to 0.20
Arnbak and Elbro (2000); Elbro and Arnbak (1996)	L	M	33	SmG (4)	12 weeks; 36 sessions; 15 min each; 9 h	9, 9-12,11 years old	RD	M	C, D, F, M, PA, PR, S, V	−0.32 to 0.21
Berninger et al. (2008)[a]	O	CM	19	SmG (8-11)	3 weeks; 28 h total; 12 h morph	4-9th	RD	M, O, S	F, S	0.25 to 0.47
Berninger et al. (2003)[a]	R	CM	10	SmG (10)	3 weeks; 28 h total; 14 h morph	5-7th	RD	C, D, M, O	D, F, PR	−1.96 to 1.94
Fillipini (2007)[a]	R	CM	8	SmG (5)	8 weeks; 6.57 h; 4.6 h morph	1st	ELL	D, M, P, V	C, D, F, PR, V	−0.18 to 1.72
Harris (2007)[a]	V	M	10	LgG	10 session; 45 min each; 7.5 h total	9th	LD	M,V	M	3.41
Henry (1987, 1988); Henry et al. (1989)[a]	L	CM	24	SmG (12 or less)	6-8 weeks; 25 session; 12-19 h morph	2-5th	LD	D, P, M, S	D, M, S	0.24 to 0.30
Kirk and Gillon (2009)[a]	L	CM	8	Ind & SmG	16-22 sessions; 45 min each; 14.5 h	8-11 years old	Poor spellers	P, S, O	D, PR, S	−0.03 to 0.26
Lovett et al. (2000)[a]	R	CM	10-20	SmG (3)	16-18 weeks; 70 h total	6.9-13.9 years	RD	D, M, O, P, S	C, D, F, PA, PR, S	−0.84 to 3.01

Table 1 (continued)

Author	Focus	Extent	*N*	Treatment unit	Length of treatment	Grade/age	Type of learner	Treatment strategy	Reading outcome	ES range
Lovett and Steinbach (1997)[a]	R	CM	12-16	SmG (2-3)	8-9 weeks; 35 h total; 15 h morph	2-3rd, 4th, 5th	RD	D, M, O, S	D, PA, PR, S	0.04 to 0.52
Roberts Frank (2008)[a]	L	CM	3, 11	LgG	33 session; 11 h total; 7.4 h morph	9th	LD	M, S	C, F	−1.45 to 1.28
Robinson and Hesse (1981)[a]	S	M	62	LgG	8 month; 47-82 h total	7th	Poor spellers	M, S	M	−0.07
Tomesen and Aarnoutse (1998)	V	CM	8	SmG (4)	6 weeks; 12 sessions 9 h total	4th	Poor Comp	M, V	C, V	1.04 to 3.37
Tyler et al. (2002)[a]	O	M CM	20	I & SmG (3)	24 weeks; 30 hrs total; 15 h morph	Pre-school 3-5; 11 years	SLD	P, M	M, P	0.28 to 1.27
Tyler et al. (2003)[a]	O	M CM	40	I & SmG (3)	24 weeks; 30 h total; 15 h morph	K- 3-5; 11 years	SLD	P, M	M, P	0.53 to 1.56
Vadasy et al. (2006), study 1[a]	R	CM	12	Ind	20 weeks; 40 h total; 20 h morph	2nd	SR	D, M, O, P, S	C, D, S	0.64 to 0.84
Vadasy et al. (2006), study 2[a]	R	CM	21 11	Ind	36 h total; 11 h morph	2-3rd	SR	D, M, O, P, S	C, D, F, S	−0.16 to 0.62

M morphological only, *CM* comprehensive intervention, *LgG* 15 or more students, SmG (number of students defined), *Ind* individual, *ELL* English language learners, *LD* learning disabled, *RD* reading disabled, *SLD* speech and language disabled, *SR* struggling readers, *P* phonological, *D* decoding, *C* comprehension, *M* morphological, *PA* phonological awareness; *PR* phonological recoding, *S* spelling, *V* vocabulary

[a] Interventions in English

For example, working with fourth-seventh graders with reading disabilities, Abbott and Berninger (1999) did not find any significant group differences on standardized measures of word identification, although these researchers noted a trend toward individual improvement in standardized measures of word identification of real and pseudo words and spelling with participants improving one third of a SD on standardized measures of decoding. On the other hand, Berninger et al. (2003) showed fifth-seventh graders with reading disabilities improved significantly more than a phonological comparison group in phonological decoding efficiency and in accuracy and time for morphological decoding as the result of a comprehensive intervention including 14 h of morphological instruction. Similarly, Berninger et al. (2008) showed that fourth-ninth graders with dyslexia who scored more than 1 SD below their verbal IQ on decoding and spelling standardized measures improved in spelling, decoding, morphological awareness, and composing as the result of a 12-h morphological spelling component which was part of a 28-h general writing intervention with η_p^2 ranging from 0.14 to 0.50. No measure of comprehension was included in these studies.

Variability of findings is also highlighted by Vadasy et al. (2006) who reported improvements in comprehension, decoding, and spelling for second grade struggling readers who performed below the 37th percentile on a composite decoding test (study 1) and improvements in comprehension and decoding for second and third grade struggling readers (study 2) as the result of individual instruction provided by paraeducators that included morphological instruction in addition to more general reading instruction. For example, average effect sizes across studies were different (0.84 in study 1 compared to 0.57 in study 2) as were effect sizes for reading accuracy (0.71 in study 1 compared to 1.06 in study 2) and effect sizes for reading comprehension (0.75 in study 1 compared to 0.32 in study 2). These differences in effects, although all positive, suggest the need for a meta-analysis to synthesize findings across multiple studies.

Studies by Katz and Carlisle (2009), Carlisle (2007), and Edwards (1982) employed single subject design. Katz and Carlisle's (2009) study, also discussed in Carlisle (2007), highlights the variability of effects of morphological instruction. Katz and Carlisle (2009) examined three case studies of struggling readers in fourth grade receiving a 12-week intervention consisting of 30-min lessons that involved affix instruction, identification of morphemes through word sorts, and word building activities. For these students, effects sizes ranged from −0.40 to 0.47 for measures of word identification, from 0.27 to 1.2 for passage comprehension, and from −0.27 to 0.93 for vocabulary. Differences such as these emphasize the need to combine findings across studies.

The study by Henry (1987, 1988) and Henry, Calfee, and Avelar-LaSalle (1989) highlights differences in results between students with reading disabilities and classmates. These researchers showed that students with learning disabilities who received a 5-week intervention that focused on improving literacy outcomes through study of word origins and word structure patterns made significant gains in reading, spelling, and word structure knowledge. Furthermore, "the learning disabled students also exhibited qualitatively different results following instruction. They began using technical decoding terminology… and used alternative strategies to spell longer, new words. Meg said that to read an unfamiliar long word, 'You find the prefixes and suffixes—or if it's a compound. Then go to syllables and then to letters" (Henry et al. 1989, p. 159). Similarly, Robinson and Hesse (1981) reported that low and average achieving seventh graders who received morphological spelling instruction through a curriculum entitled *Corrective Spelling Through Morphographs* made greater gains than high achievers, although all students improved in spelling and morphological rule application, but not in morphological awareness. Like these earlier

studies, Nunes et al. (2006) reported gains on researcher made vocabulary measures for third-seventh graders, with students who scored poorly on the pretest seeming to improve more than higher achievers.

Effects in languages other than English

Morphological interventions in languages other than English also show improvement in literacy outcomes, but again emphasize variability in findings (Arnbak & Elbro, 2000; Elbro & Arnbak, 1996). Arnbak and Elbro's (2000) intervention, also discussed in Elbro and Arnbak (1996), showed positive benefits for children with dyslexia with at least a 2-year discrepancy between reading age and chronological age who were randomly selected from remedial reading classes. By providing morphological training three times a week for 12 weeks, Arnbak and Elbro (2000) recorded improvements in measures of morphological awareness, reading comprehension, reading of real words, reading of roots, and spelling accuracy in fourth and fifth graders with dyslexia. This study also showed neither phonological deficits nor level of cognitive skills in students with dyslexia predicted individual differences in responses to morphological training. It is important to note that large differences among participants were noted by these researchers, with results on morphological measures significant only by school.

Features of morphological interventions

Morphological interventions also differ by instructional goals and strategies used. Because morphological awareness is related to other aspects of language such as decoding, comprehension, grammar, and spelling, morphological interventions involve various morphological instructional strategies. Table 2 identifies 16 morphological teaching strategies, including affix and root word instruction, identifying affixes and root words, building words from morphemes, compound word instruction, emphasizing inflectional morphological awareness, linking morphemes to grammar, teaching morphological patterns and rules, distinguishing between morphemes and pseudomorphemes, using context, word family instruction, identification of words by analogy, instruction in word origins, using word sorts to highlight morphological features, and word mapping.

Examples of the implementation of these strategies include Katz and Carlisle's (2009) teaching of common suffixes and prefixes and then using this knowledge to identify affixes and base words in speeded drills. These researchers similarly used word sorts to highlight morphological features, asking participants to sort words into categories based on word structure, Berninger et al. (2003) also used word sorts to help students identify morphological rules. For example, they had students sort words such as *realize, rewind, recapture, ready, and reach* into 'prefix' or 'not a prefix' categories, helping students discover that a prefix cannot be identified from spelling alone. Kirk and Gillon (2009) also used word sorts to highlight morphological features, but they were careful to include only words that fit the rule rather than exception words. Word building was another morphological strategy used, with Berninger et al. (2003) using cards with affixes and bases to build words such as *dislike, scientist, mouthful, and northern*. Instruction in word origins such as patterns and rules regarding Latin, Greek, and Anglo-Saxon words is another example of morphological teaching (Abbott & Berninger, 1999; Henry 1987, 1988; Henry et al. 1989; Roberts Frank 2008).

Table 2 Types of morphological instruction

Study	Affix meanings	Root words	Seeking part you know/ identify affixes and roots	Building words	Compound words	Emphasis on inflectional morphology	Links to grammar	Morpheme pattern/ rules	Morphemes vs. psuedo-morphemes	Relate Morphemes to spelling	Using context	Word families	Word identification by analogy	Word mapping/ word matrices	Word origin	Word sorts
Abbott and Berninger (1999)			√					√		√					√	
Arnbak and Elbro (2000); Elbro and Arnbak (1996)	√	√	√	√	√	√			√							
Berninger et al. (2008)			√	√				√		√						
Berninger et al. (2003)	√	√	√	√				√	√		√	√				√
Fillipini (2007)	√		√	√		√	√	√								
Harris (2007)	√	√	√											√		
Henry (1987, 1988); Henry et al. (1989)	√	√	√	√	√			√		√					√	
Katz and Carlisle (2009); Carlisle (2007)	√	√	√	√							√	√			√	√
Kirk and Gillon (2009)	√	√	√					√		√	√					√

Table 2 (continued)

Study	Affix meanings	Root words	Seeking part you know/ identify affixes and roots	Building words	Compound words	Emphasis on inflectional morphology	Links to grammar	Morpheme pattern/ rules	Morphemes vs. psuedo-morphemes	Relate Morphemes to spelling	Using context	Word families	Word identification by analogy	Word mapping/ word matrices	Word origin	Word sorts
Lovett et al. (2000)	√		√		√								√			
Lovett and Steinbach (1997)	√		√		√								√			
Roberts Frank (2008)	√	√		√				√		√					√	
Robinson and Hesse (1981)			√	√				√		√						
Tomensen and Aarnouste (1998)			√								√					
Tyler et al. (2003)	√					√	√	√								
Tyler et al. (2002)	√					√	√	√								
Vadasy et al. (2006) – Study 1			√					√		√						
Vadasy et al. (2006) - Study2			√					√		√						

Further examples include emphasis on the role of inflectional morphology, including one third of Arnbak and Elbro's (2000) intervention focusing on the consequences of inflectional morphemes as in the example, "What is the difference between 'a murdering man' and 'a murdered man'?" (p. 236). Other studies focuses on the role of morphemes in spelling, as in Kirk and Gillon's (2009) example of teaching participants that the consonant of the base morpheme doubles when adding a suffix. Compound word instruction also occurred, with Arnbak and Elbro (2000) having students separate compounds into component words and Lovett et al. (2000) using "I-Spy" to help students find words within compound words, such *baseball, blueberry, and fireplace.* Finally, word mapping was used to separate the morphemes within a word and relate morphemes to those with similar meanings or word parts as Harris (2007). Because these studies differ by strategies used, it is important to synthesize the findings across studies to determine the overall effect of general morphological instruction.

Variations across studies

A consistent theme to the discussion of morphological interventions has been variability and therefore the main challenge in determining the overall effect of morphological instruction on literacy achievement stems from differences across studies such as variation in instructional strategies, goals, length, intensities, research designs, participants, number of students in an instructional group, title of who implemented the intervention, and reporting of findings. For example, some interventions focused on improving reading achievement (Berninger et al. 2003; Lovett & Steinbach, 1997; Roberts Frank 2008), spelling (Robinson & Hesse, 1981), vocabulary knowledge (Harris 2007; Tomesen & Aarnoutse, 1998) or multiple literacy goals (Abbott & Berninger, 1999; Henry et al. 1989; Lovett et al. 2000; Vadasy et al. 2006). Similarly, morphological instruction differed as shown in Table 2, as did size of instructional groups which ranged from individual to large group instruction. Number of participants in the intervention also differed, ranging from eight to 62 participants.

Another area of variability was the research design and statistical analyses used in the studies. For example, number and type of comparison/control groups, group assignment, matching, and assessment measures differed across studies. Table 1 highlights these differences.

A third area of variability was the level of reporting present in these studies. Some studies included detailed analysis of the intervention, research design, participants, and measures used, but others did not report the reliability of the measures used, the specific instructional strategies used in their intervention, group assignment procedures, drop-out information, nor effect sizes.

To address the aforementioned observed variations in study findings, we have used a meta-analytic technique to compute the overall effect and further compare its effect by several factors that might lead to variations in study findings. Meta-analysis, or the "analysis of analyses," which is a term coined by Gene Glass (1976), is a tool that enables researchers to evaluate similarities across studies, and if not, to explore the sources of variations in study results. Variations in study findings can be explained by several study characteristics such as different settings, treatment implementations, types of participant, and types of measures. This can be accomplished by running moderator analyses (i.e., analysis of variance (ANOVA)-like categorical analysis and regression analysis), which are particularly useful for identifying systematic differences in study findings.

Specifically, meta-analysis follows the same steps as other primary studies. Cooper (2009) laid out seven stages of meta-analysis: formulating problem, searching the literature,

gathering information from studies, analyzing and integrating the outcomes, interpreting evidence, and presenting results. More details regarding these seven stages can be found in Cooper (2009). By following these steps systematically, the potential bias threatening the validity of study finding can be controlled. Also, since meta-analysis is statistically more powerful than primary individual studies, results of this analysis will yield more reliable and generalizable conclusions (Cooper 2009). For these reasons, meta-analysis is our method of choice in investigating the beneficial effect of morphological intervention on improving children's literacy achievement and exploring systematic differences by several characteristics that were identified in the literature.

Methods

Selection of studies

The location of relevant studies was as exhaustive as possible, and included both published and unpublished literature based on a manual as well as a computerized search of four databases including ERIC, Education Full Text, PsycINFO, and Dissertation Abstracts Online Database. A final list of the key terms for literature searches included *morphology, morphemes, morphological awareness, intervention, instruction, learning disabilities, student characteristics, language impairments, reading difficulties, reading ability, vocabulary development, reading, structural analysis, and language processing* from 1980 to present. In addition to computerized database resources, cross-checking of references, scans of journals, and expert contacts[1] ensured an extensive literature search.

Studies retrieved from the initial searches were screened using the following criteria:

- The intervention included a morphological component with emphasis on morphemes as units of meaning.
- Study must use the pretest-posttest control-group design.
- Study must have a control group that is compared to morphological intervention group(s).
- The intervention must include at least one morphological component with an emphasis on morphemes as units of meaning.
- The participants must be school aged (preschool-twelth grade).
- Study must have been written in English.
- If the same subjects are used in multiple literatures (e.g., Henry 1987, 1988; Henry et al. 1989; Arnbak & Elbro, 2000; Elbro & Arnbak, 1996), the authors combine them to obtain independent effect sizes from the most comprehensive dataset.
- Study must have been published since 1980[2].

[1] Authors attended several educational and reading conferences such as the American Educational Research Association, Council for Exceptional Children Convention & Expo, Society for the Scientific Study of Reading, Institute for Educational Sciences Annual Conference, and the National Reading Conference and polled experts to find any studies that were never published or upcoming unpublished studies related to morphological instruction.

[2] Time frame of studies published since 1980 was chosen based on the history of the study of morphological awareness in relation to literacy. For example, in the 1970s, researchers seemed focused on examining the correlations between morphological awareness and general reading measures (Britain 1970) whereas by the 1980s, researchers determined the frequency of morphologically complex words in text (Nagy & Anderson, 1984) and began to study morphological interventions (White, Sowell, & Yanagihara, 1989; Wysocki & Jenkins, 1987).

- Study must provide sufficient statistics for computing effect size such as mean, standard deviation, and sample size for each group.

This selection identified a total of 19 references. Out of these studies, three single subject studies (i.e., Carlisle 2007; Edwards 1982; Katz & Carlisle, 2009) were excluded. The remaining 16 studies provided 17 independent studies with a study providing five independent studies (two from Vadasy et al. (2006)), and all studies provided at least one literacy achievement outcome. A total of 17 independent studies met the inclusion criteria for analysis and were used in the current meta-analysis.

Coding of studies

A number of characteristics reflecting potential moderators for the effectiveness of morphological instruction of school-aged children who tend to struggle with literacy were coded. These characteristics include (a) study design, (b) participants, (c) type of reading instruction, and (d) measure of literacy achievement. Table 1 shows the characteristics of the included studies in more details.

Design characteristics Samples were classified as either intervention or control groups. All intervention groups received some type of morphological instruction, which was given alone or as part of larger intervention. Control groups included participants who received other types of instruction with no morphological components (e.g., contextual instruction or phonological instruction). Samples were also coded for (a) which methods were used to assign participants into morphological intervention groups, (b) whether participants were dropped, and (c) whether participants were matched on certain characteristics such as parental education level, reading level, participant's age, and free or reduced lunch status. These characteristics were coded solely based on author's descriptions.

Participant characteristics Types of learners were coded and classified as LD, reading disabled (RD), speech and language delayed (SLD) children, poor readers, struggling readers, and/or poor readers/spellers, and English Language Learners (ELL).

Morphological instruction characteristics The extent of the intervention in terms of whether it involves only morphological instruction (M) or morphological instruction as part of a more comprehension intervention (M+), total intervention hours per session (0-5, 6-10, 11-20, 21-41, and more than 40 h), total morphological intervention hours per session (0-5, 6-10, 11-20, and more than 20 h), the additional instructional strategies and intervention unit (individual, small group less than 12, and large group) were coded. In addition, morphological teaching strategies were grouped into categories (affix instruction, focus on parts, morpheme patterns/rules, and vocabulary related morphological instruction). Based on Table 2, affix instruction included instruction of affix meanings, root words, and word origin instruction. Focus on parts included seeking a part you know, building words, and compound word instruction. Morpheme patterns/rules included links to grammar, morphemes vs. pseudo-morphemes, relating morphemes to spelling, and word identification by analogy. Vocabulary related morphological instruction included using context, word families, and word mapping/word matrices.

Literacy achievement Studies were coded, placing the measures of literacy achievement outcomes into eight broad categories: measures of reading comprehension, decoding, fluency, morphology, phonological awareness, phonological recoding, spelling, and vocabulary. These

outcomes were chosen because of their relation to reading achievement. For example, decoding, comprehension, and fluency assess components of reading, whereas measures of morphology, phonological awareness, and phonological recoding involve processing language at the sub-lexical level. Vocabulary is related to reading achievement through connecting decoded representations with meaning. Psychometrics of these measures including whether assessments were standardized or researcher-made, whether reliabilities or validities of measures were reported, and number of items were also coded.

Focus of the intervention Studies were coded for the focus of the intervention (literacy, reading, spelling, vocabulary, or other) based on the author's discussion of the purpose of the intervention. For example, studies that aimed to improve reading and spelling achievement were categorized as literacy focused whereas studies that aimed to improve decoding and reading comprehension were categorized as reading focused. Studies that aimed to improve writing or language achievement were categorized as other.

Computation of effect sizes

The primary index used in this meta-analysis is the standardized mean-change difference between treatment and control groups (Becker 1988). The standardized mean-change difference (d_{ppc}), which corresponds to the difference between the standardized mean change for treatment and control groups[3], is often used for the pretest-posttest control-group design (Morris 2008). The associated variance[4] was computed based on the formula provided by Becker (1988), which is fully described in Morris (2008).

Analyses

Our statistical analyses were based on methods proposed by Hedges and Olkin (1985) and also described in Cooper, Hedges, and Valentine (2009). This meta-analysis used the variance-weighted analyses developed by Hedges and Olkin (1985) and therefore, under the fixed-effect model, the overall weighted average mean-change difference ($\overline{d}$) was computed by weighting the unbiased effect size (d_i) by the inverse of its associated variance ($v_{(\text{di})i}$), which is shown in the formula (Morris 2008 p. 371).

[3] The standardized mean-change difference between treatment and control group was computed using the formula proposed by Becker (1988) $d_i = \left(1 - \frac{3}{4(n_{T_i}-1)-1}\right)\left(\frac{M_{\text{post},T_i} - M_{\text{pre},T_i}}{\text{SD}_{\text{pre},T_i}}\right) - \left(1 - \frac{3}{4(n_{C_i}-1)-1}\right)\left(\frac{M_{\text{post},C_i} - M_{\text{pre},C_i}}{\text{SD}_{\text{pre},C_i}}\right)$ where n_{T_i} and n_{C_i} are sample sizes for treatment and control groups for the ith study; M_{pre,T_i} and M_{pre,C_i} are means of the pretests for treatment and control group for the ith study $\text{SD}_{\text{pre},T_i}$ and $\text{SD}_{\text{pre},C_i}$ are standard deviations of the pretests for treatment and control group for the ith study.

[4] The variance of d_i is computed by the formula proposed by Becker (1988)

$$v_{(d_i)_i} = \left(1 - \frac{3}{4(n_{T_i}-1)-1}\right)^2 \left(\frac{2(1-r_i)}{n_{T_i}}\right)\left(\frac{n_{T_i}-1}{n_{T_i}-3}\right)\left(1 + \frac{n_{T_i} d_{T_i}^2}{2(1-r)}\right) - d_{T_i}^2$$
$$+ \left(1 - \frac{3}{4(n_{C_i}-1)-1}\right)^2 \left(\frac{2(1-r_i)}{n_{C_i}}\right)\left(\frac{n_{C_i}-1}{n_{C_i}-3}\right)\left(1 + \frac{n_{C_i} d_{C_i}^2}{2(1-r)}\right) - d_{C_i}^2$$

Where r_i is a correlation between pretest and posttest score; d_T and d_C are standardized mean difference between pretest and posttest for treatment and control groups.

The computation of the variance of the standardized mean-change difference requires the correlation between pretest and posttest for the *i*th group. However, four studies provided correlation (r_i) between pretest scores *X* and posttest scores *Y*, which ranged from 0.52 to 0.89. Thus, for studies that did not provide r_i, the average[5] of the reported correlations (0.63), was used for computing the variance of the standardized mean-change difference.

An overall homogeneity test of effects was used to determine whether all effects were from the same population. When the overall homogeneity does not hold (i.e., Q_{total} is not significant), then the overall effect size was computed under the random effects models[6], which incorporate additional between-studies uncertainty to the effect sizes (Raudenbush 2009). Cooper (1989) suggests that the meta-analyst should choose a random effects model in cases where the effect sizes in a data set are likely to be affected by a large number of uncontrollable influences such as the differences in the teachers and schools sampled and the specific measures used. Raudenbush also indicates that, if the outcome of a process cannot be predicted in advance due to a multiplicity of potential moderators, it would be reasonable to consider a study's true effect size as random. Under the mixed-effects model, the predictor variables are included and the additional between-study uncertainty in the variances is also incorporated.

Further, ANOVA-like categorical models with categorical moderators (e.g., types of reading outcome, grade level) were applied to explore if study features explain between-group variations in effect sizes (i.e., Q_{between} is significant). When there is still unexplained variances left (i.e., *Q* is significant), mixed-effects models[7] with moderators were performed. Under the mixed-effects model, additional uncertainty is incorporated within each level of categorical moderators and the between-studies uncertainty. More details can be found in Raudenbush (2009).

Dependence

Independence of effect sizes is an important assumption for most of statistical analysis. Outcomes that have been evaluated for the same participant or outcomes that are measured at different time points for the same participants violate this assumption of independence (Gleser & Olkin, 1994). As suggested by Becker (2000), issues of dependence can be dealt with in various ways.

This meta-analysis separated effects into categories so that effects were no longer dependent each other. For example, effects were grouped by the types of literacy achievement measure, which eliminated some of the dependence issues, yet left effects that were computed from multiple measures of the same types of reading achievement still dependent. To resolve this issue, effect sizes based on the most valid and reliable measures of the types of reading outcome were used. For example, measures with scores with reliabilities over 0.8 (Norcini 1999) were chosen over measures with lower reported reliabilities. In terms of validity, as suggested by Osterlind (2006), measures that "produce useful and meaningful information that supports appropriate decisions" (p. 87) and which therefore most closely assess the outcome were chosen. For

[5] The correlation of 0.5 is often used as a default to compute the variance of the standardized mean-change for studies which do not provide it (Netz, Wu, Becker, & Tenenbaum, 2005). However, we imputed missing values using the average of the reported correlation values of 0.63, which can be better estimate of missing correlation coefficients between pretest and posttest.

[6] The random-effects model incorporated additional uncertainty to the effect variances, which was estimated using the methods of moments as $\hat{\sigma}_\delta^2 = \left(\sum (d_i - \overline{d})^2/(k-1)\right) - \overline{v}$ where $\overline{v}$ is the average of within-study variances ($v_{(d_i)}$) across the *k* effects in the analysis. Thus, the weights for random-effects (w_i^*) were computed as $w_i^* = 1/(v_{d_i} + \hat{\sigma}_\delta^2)$, where $\hat{\sigma}_\delta^2$ was estimated using the method of moments estimation.

[7] The mixed-effects model with categorical moderators incorporated additional uncertainty within each level of categorical moderators, whose weights were computed as $w_{ij}^* = 1 \Big/ (v_{(d_i)_i} + \hat{\sigma}_{\delta_j}^2)$ for effect *i* in the level of moderators *j*.

example, Arnbak and Elbro (2000) reported seven measures of decoding achievement, but the measure of reading real words was chosen to be included in the analysis because it represented a productive measure of transfer, which seemed to assess both what the student learned and whether they could apply those skills to decode real words.

Coding reliability

Study features described above were coded by two independent reviewers. Coding reliabilities, computed as the percentage of agreement of the coded variables before resolution upon discussion, ranged from 87% for the focus of reading intervention to 100% for publication type. Also, Cohen's Kappa ranged from 0.92 to 1.00 indicated fairly good coding reliability. Coding discrepancies mainly arose over the extent of the intervention and types of literacy measures. All discrepancies were resolved upon discussion before analyzing data.

Results

Description of effects

A total of 17 independent studies allowed for 79 standardized mean-change differences[8] between control and treatment group. When studies included multiple subgroups, effect sizes were computed for as many specific groups for which data were available. For example, Lovett et al. (1997) provided three separate effect sizes by grade levels (second and third, fourth, fifth and sixth grade level), which provided three effect sizes.

Studies included published journal articles, dissertations, book chapter from between 1981 and 2010. Five of them were conducted in different countries including Denmark (s=1), Netherlands (s=1), New Zealand (s=1), and Canada (s=2) and two studies were based on the intervention in a different language other than English. Average total sample size ranged from 15 to 261 (M=40.35, SD=47.18). Specifically, the intervention group sample size ranged from 8 to 164 (M=21.84, SD=30.22) and the control group sample size ranged from 7 to 97 (M=18.52, SD=17.68). Participants with a wide range of grade levels (K-12) were included in the current meta-analysis.

Out of 79 effect sizes, different numbers of effect size (k) were extracted depending on the measures of children's literacy outcomes: reading comprehension (k=10), decoding (k=11), morphological awareness (k=12), phonological awareness (k=16), spelling (k=11), vocabulary (k=4), phonological recoding (k=7), and fluency (k=8). Type of learners also varied. These included children with learning disabilities (k=6), reading disabilities (k=38), children with SLD (k=16), struggling readers (k=7), and poor readers/spellers (k=6), and ELLs (k=6). Total average hours of the morphological interventions were 20.02 with a standard deviation of 18.13.

Publication bias

Publication bias often arises when the publication status depends on the statistical significance of study results (Sutton 2009). One way to assess whether publication bias is likely to be

[8] Effect sizes from two studies (Harris 2007; Robinson & Hesse, 1981) were extremely huge. After cross-checking of statistics that are associated with unbelievably huge effect sizes, we deleted two effect sizes obtained from Harris (2007) and Robinson and Hesse (1981). We suspect that these large effects stem from reporting errors of statistics.

problematic for a set of studies is to examine the funnel plot. Since effect sizes from smaller studies show more variability than those from larger studies, a plot of mean effect sizes against sample sizes should resemble a funnel if publication bias is not problematic.

As shown in Fig. 1, the funnel plot of effect sizes seems to be a bit asymmetric, having a bit more positive effect sizes. Further, the Egger's regression test for funnel plot asymmetry was statistically significant (t=3.49, p=0.001), indicating that publication bias might exist. However, for this review, publication bias should not be a problem because both published and unpublished studies were included. Also, the moderator analysis indicates that no significant mean effect size difference exists by publication type ($Q_{between}$ (2)=2.07, shown in Table 3).

Overall effect of morphological intervention

A homogeneity test of 79 standardized mean-change differences representing the effect of morphological intervention on reading outcomes, Q_{total} (78)=182.38, p<0.01, indicated that the effects were not from the same population. Thus, the overall mean effect of morphological intervention was computed under the random effects model, which allows for the incorporation of additional error and therefore provides more conservative estimates of the effects of morphological instruction on literacy outcomes. Under the random effects model, the weighted-mean effect of morphological intervention was 0.33 with a standard error (SE) of 0.07, having a 95% confidence interval (CI) ranging from 0.18 to 0.47. Such result indicated that the overall effect of morphological intervention on literacy outcome was statistically significant, moderate,

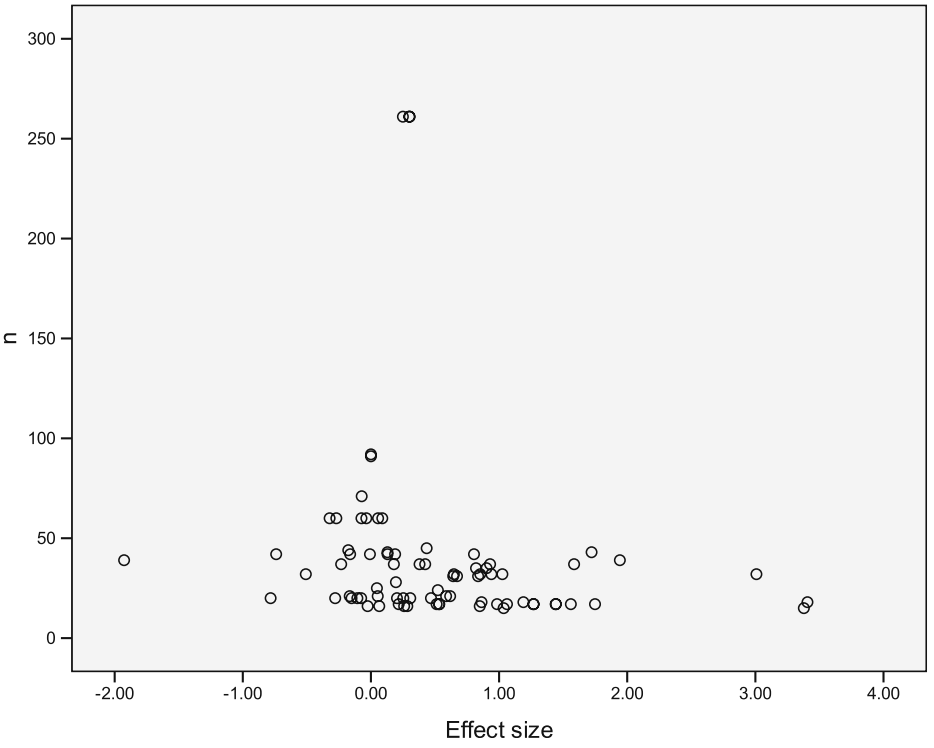

Fig. 1 Funnel plot of all 79 standardized mean-change difference

Table 3 Effects of morphological intervention

Source	k	$\overline{d}$	SE	z	95% CI		Q_{within}
					UL	LL	
Overall, Q_{total} (78)=182.38**	79	0.33**	0.07	4.42	0.18	0.47	
Extent of intervention, $Q_{between}$ (1)=12.25**							
Morphological intervention only	12	−0.05	0.13	−0.50	−0.22	1.12	24.53**
Morphological intervention plus	67	0.36**	0.08	4.23	0.19	0.53	145.60**
Focus of intervention, $Q_{between}$ (4)=40.43**							
General literacy[a]	17	−0.10*	0.05	−2.53	0.03	0.24	6.01
Reading	40	0.39**	0.05	5.21	0.17	0.38	70.87**
Spelling[a]	1	−0.72	0.59	−0.12	−1.22	1.08	0.02
Vocabulary[a]	3	1.72**	0.52	3.31	0.70	2.74	4.26
Other	18	0.48**	0.14	3.61	0.22	0.74	60.80**
Average hours of morphological intervention, $Q_{between}$ (3)=21.65**							
0–5 h	14	0.29	0.22	1.34	−0.14	0.58	37.89**
5–10 h[a]	9	0.15	0.38	0.38	−0.60	0.06	14.56
10-20 h	31	0.31**	0.06	5.07	0.19	0.43	65.72**
More than 20 h	25	0.32**	0.08	4.10	0.17	0.47	42.57**
Type of literacy outcome, $Q_{between}$ (7)=29.12**							
Reading comprehension[a]	10	0.24**	0.09	2.61	0.06	0.42	8.08
Decoding	11	0.23	0.26	0.88	−0.28	0.73	64.15**
Morphological awareness[a]	12	0.40**	0.11	3.74	0.19	0.61	15.06
Phonological awareness[a]	16	0.49**	0.11	4.61	0.28	0.70	18.96
Spelling[a]	11	0.20**	0.08	2.43	0.04	0.36	18.59
Vocabulary[a]	4	0.40**	0.20	2.05	0.02	0.79	5.12
Phonological recoding	7	0.54	0.13	1.28	−0.29	1.37	17.81**
Fluency[a]	8	−0.28*	0.12	−2.37	−0.52	−0.03	5.50
Type of learner, $Q_{between}$ (5)=34.04*							
Learning disabled	6	0.22**	0.07	3.04	0.08	0.37	12.17*
Reading disabled	38	0.17**	0.13	5.99	0.52	1.02	98.81*
Speech and language disabled[a]	16	0.77**	0.07	3.11	0.62	0.91	7.45
Struggling reader[a]	7	0.46**	0.10	4.58	0.27	0.66	4.45
Poor spellers[a]	6	0.24	0.17	1.41	−0.09	0.56	4.18
English Language Learner	6	0.62**	0.18	3.44	0.26	0.97	21.29**
Unit of intervention, $Q_{between}$ (3)=4.30							
Publication type, $Q_{between}$ (2)=2.07							
Study design, $Q_{between}$ (2)=1.53							
Study location, $Q_{between}$ (1)=7.55**							
US	47	0.42**	0.11	3.89	0.21	0.63	117.01**
Non-US	32	0.26	0.03	1.90	0.06	0.52	57.82**

[a] Estimates were computed under the fixed-effects model

*p<0.05; **p<0.01

and positive (z=4.42, p<0.01), suggesting that children in the morphological intervention groups yielded more improvements on literacy outcomes when compared to control groups.

Differential effects of morphological intervention

Next, a series of moderator analyses were conducted to investigate differential effects of morphological instruction due to the extent and focus of the morphological intervention, total length of intervention, average hours of morphological intervention, intervention unit, type of reading outcome measure, and type of learner. Table 3 summarizes results from these categorical analyses that were based on the mixed-effects models, which again incorporate additional error and again provide conservative estimates of the effects of these interventions.

Extent of morphological interventions The difference between standardized-mean change for treatment and control group significantly differed depending on the extent of intervention, $Q_{between}$ (1)=12.25, p<0.01. Intervention as a part of more comprehensive instruction ($\overline{d}$=0.36, SE=0.08, 95% CI: 0.19 and 0.52) was more effective at improving children's reading achievement than an intervention with an exclusive focus on morphological instruction ($\overline{d}$=-0.05, SE=0.13, 95% CI: −0.22 and 0.12). Only intervention as a part of more comprehensive instruction was statistically significant(z=4.23, p<0.01), suggesting that morphological intervention yielded more improvement on literacy outcomes for children with difficulties when it is provided in collaboration with other research-based reading instruction.

Focus of morphological interventions The focus of the morphological intervention was categorized into general literacy (k=17), reading (k=40), spelling (k=1), vocabulary (k=3), and other (k=18). The overall weighted mean effects for five focus areas significantly differed, $Q_{between}$ (4)=40.43, p<0.01. Under the mixed-effects model, the estimated mean effects were 0.39 (SE=0.09) for reading (z=5.21, p<0.01), 1.72 (SE=0.52) for vocabulary (z=3.31, p<0.01), and 0.48 (SE=0.18) for other area such as writing or speech (z=3.61, p<0.01), which are statistically significant. Such significant results suggest that morphological instructions with the focus of reading, vocabulary, and other area yielded greater improvement on literacy outcome compared to control group.

Type of literacy outcome measure Intervention effects were reported for eight types of literacy outcome measures: reading comprehension (k=10), decoding (k=11), morphological awareness (k=12), phonological awareness (k=16), spelling (k=11), vocabulary (k=4), phonological recoding (k=7), and fluency (k=8). A significant between-group Q statistics of 29.12 (p<0.01) suggested that intervention effects differed by type of literacy outcome measure. Phonological awareness showed the largest statistically significant mean effects of morphological intervention ($\overline{d}$=0.49, SE=0.11, z=4.61, p<0.01), followed by the mean effect for morphological awareness ($\overline{d}$=0.40, SE=0.11, z=3.74, p<0.01) and vocabulary ($\overline{d}$=0.40, SE=0.20, z=2.05, p=0.04). Significant effects of morphological intervention were also found on reading comprehension ($\overline{d}$=0.24, z=2.61, p<0.01), and spelling ($\overline{d}$=0.20, z=2.43, p=0.02). However, no statistically significant intervention effects were found for decoding ($\overline{d}$=0.23, z=0.88, p=0.38). In addition, the significant negative mean-change difference of −0.28 indicates that control group showed bigger improvement on fluency outcomes than morphological treatment group.

Average hours of morphological interventions Average hours of the morphological intervention were categorized into five subgroups: 0-5, 5-10, 10-20, and 20 h above. The overall means were different depending on average hours of morphological interventions, $Q_{between}$ (3)= 21.65, $p<0.01$. Morphological interventions with an average 10-20 h instruction showed the largest statistically significant mean effect of 0.31 (SE=0.06), followed by the almost identical statistically significant effect of 0.32 (SE=0.08) by the morphological intervention with more than 20 h instruction. Insignificant mean-change differences were found when average hours of morphological intervention were either 0-5 (z=1.34, p=0.18) or 5-10 h (z=0.38, p=0.70).

Intervention unit Unit of intervention was categorized into four groups—individualized, small groups with less than 12, large group, and combined. The insignificant between-group Q statistics of 4.30 (p=0.23) implies that the standardized mean-change differences were not statistically different depending on the unit of intervention. The weighted-estimated mean-change differences were all positive, with the largest mean effect for small group instruction.

Type of learner A categorical analysis showed that intervention effects differed by type of learner ($Q_{between}$ (5)=34.04, $p<0.01$). Mean values were statistically significant for children with RD, children with learning disabilities, children with SLD, English language learners, and struggling readers (SR), showing the beneficial effects of morphological instruction on improving these children's literacy achievement. In particular, children with speech and language delay showed the largest intervention effect on improving their literacy outcomes ($\overline{d}$= 0.77, SE=0.07, z=3.11, $p<0.01$), followed by English Language Learners ($\overline{d}$=0.62, SE=0.18, z=3.44, $p<0.01$), struggling readers ($\overline{d}$=0.46, SE=0.10, z=4.58, $p<0.01$), children with learning disabilities ($\overline{d}$=0.22, SE=0.07, z=3.04, $p<0.01$), and children with reading disabilities ($\overline{d}$=0.17, SE=0.13, z=5.99, $p<0.01$).

Other study characteristics

Other moderators including study design (experimental designs with random assignment, quasi-experimental design, or non-experimental design), publication type (peer-reviewed journal, dissertation, and book chapter), and study location (US vs. non-US) were also examined. Only study location showed the significant mean-change difference under the mixed-effects models ($Q_{between}$ (1)=7.55, $p<0.01$). In particular, mean effect from studies published in US ($\overline{d}$=0.42, SE=0.11) was statistically significant, showing that morphological intervention in US yielded a significant improvement on literacy achievement. However, other study characteristics including study design ($Q_{between}$ (2)= 1.53, p=0.46) and publication type ($Q_{between}$ (2)=2.07, p=0.36) did not explain between-group variations.

Discussion

This meta-analysis of 17 independent studies examining morphological interventions shows that morphological interventions are successful, with the level of success differing depending on the literacy outcome. Statistically significant medium mean effect sizes were found for phonological awareness ($\overline{d}$=0.49), morphological awareness ($\overline{d}$=0.40), and vocabulary ($\overline{d}$=0.40), reading comprehension ($\overline{d}$=0.24), and spelling ($\overline{d}$=

0.20). The difference between overall mean change for treatment and control groups ranged from 0.24 to 0.49, showing that the groups receiving morphological instruction showed significantly larger improvements on reading outcomes that were between a quarter of a standard deviation unit to a half of a standard deviation larger compared to control groups. These results suggest that morphological interventions can successfully improve reading, spelling, and vocabulary outcomes at the sublexical, lexical, and supra-lexical levels for struggling readers and spellers as defined as students with learning and/or reading and/or speech and language disabilities, low achievers in reading and/or spelling, students performing below proficiency on standardized state tests, and students at high risk for reading difficulties based on current testing.

These findings indicate that morphological instruction should be included in remediation and instructional efforts with these struggling learners. Why are these findings important? Currently, morphological instruction is not a major component of instruction (Abbott & Berninger, 1999; Henry 2003; Hurry et al. 2005), yet this study shows that instruction in units of meaning improves literacy achievement for students who struggle with literacy and is particularly effective for ELLs, children with RD, children with LD, children with SLD, and SR. As a result, morphological instruction has the potential to support literacy achievement for low achieving students who need additional support learning to read and spell. This analysis suggests that for these students, morphological instruction could be embedded within classroom teaching across grade levels, allowing students to focus on meaning within text rather than isolated subskills and possibly lead to enhanced student learning.

Particularly, this study shows that morphological instruction can improve phonological and morphological awareness. According to Stanovich (1996) and Shankweiler et al. (1995), students with reading disabilities and poor readers tend to struggle on phonological awareness tasks because of difficulties with phonological processing. Instruction in morphological relationships seems to improve phonological awareness, perhaps because with more difficult word pairs, it is difficult to separate these linguistic dimensions from one another, and therefore instruction in one is likely to improve the other. For instance, when determining the connection between *magic* and *magician* where the derivational morpheme *ian* changes both the meaning of the word and the pronunciation of the/c/, resulting in a both a phonological and morphological change, a reader must use both morphological and phonological awareness to process this change. This overlap between phonological and morphological awareness shows the potential effect of morphological instruction to improve awareness of both morphological and phonological relationships, which are key sublexical processes that relate to reading achievement (Adams 1990; Carlisle 2003; Kuo & Anderson, 2006; Stanovich 1996).

The remaining sublexical process, phonological recoding, did not show statistically greater improvement by morphological interventions. This finding is expected because phonological recoding tasks involve pseudowords that are by definition pretend words without meaning, and therefore, application of units of meaning should provide little support to such pseudowords.

At the lexical level, morphological awareness significantly improved vocabulary knowledge and spelling, but did not have a significant effect on decoding. This lack of significance may result from the measures of decoding used in the studies. For example, most studies used the Woodcock Johnson Letter-Word Identification task, which involves decoding more morphologically simple words than morphologically complex words. Yet, Anglin's (1993) analysis of text shows that from third grade on, 60-80% of words in texts are morphologically complex derived words. With the morphophonemic nature of English where decoding follows

morphological rules, the question remains as to whether morphological instruction improves decoding of standard text with a majority of morphologically complex words.

In terms of spelling achievement, morphological instruction improved spelling outcomes moderately, showing that teaching students about the morphological rules that relate to spelling can help students apply those rules in their work and perhaps even recognize morphological relationships within the orthography.

Morphological interventions also improved vocabulary, which shows that direct instruction in units of meaning and word structure can help students determine the meaning of unfamiliar words. As Nagy and Scott (2000) write, "It is hard to overstate the importance of morphology in vocabulary growth" (p.275). This study supports Anglin's (1993) statement, "[Children] analyze the morphological structure of complex words so as to figure out their meanings, which they can apply to words that they have not actually learned before" (p. 152). For example, knowledge of the meanings of affixes and root words, instruction in how to identify such morphemes, and joining the meaning of each morpheme together into the meaning of the whole word seemed to be successful in supporting students with literacy challenges in their quest for identifying a word's meaning.

Because the goal of reading is to access meaning from text, perhaps the most important finding of this analysis is that morphological instruction improves reading comprehension. Whether due to the improvements in sublexical processing or greater vocabulary knowledge, students who had morphological instruction were better able to comprehend text. This is a particularly impressive finding due to the fact that most of the measures of comprehension used did not have the 60-80% of words in texts that were morphologically complex, and as a result, did not truly tap into the potential of morphological instruction to support comprehension.

Because classroom instruction rarely occurs in isolation, the greater effect of morphological instruction as part of a comprehensive intervention and the effectiveness of such instruction regardless of the size of unit of instruction suggests the potential of morphological teaching when incorporated into a classroom environment. For example, multiple aspects of literacy are addressed in a single language arts lesson and instruction often rotates from large to small to individual instruction. Because many of the interventions in this meta-analysis involved morphological instruction in addition to research based literacy instruction, these findings show the importance of combining morphological instruction with other important classroom literacy components for students.

One challenge in this analysis was that interventions used multiple teaching strategies, and therefore, we were not able to parse apart which morphological teaching strategies resulted in the largest literacy gains. We were able, though, to identify that interventions focused on improving reading, vocabulary, and other areas had the largest impact. This seems to suggest that vocabulary and reading goals align particularly well with morphological instruction.

Currently, too many children and adolescents are struggling to learn to read (Lee, Grigg, & Donahue, 2007). The present study suggests that morphological instruction is an effective way of improving the literacy outcomes of students with disabilities as well as low achieving readers, spellers, students who scored below proficiency on their state standardized test, and students at risk for reading difficulties due to their scores on phonological awareness tasks. As a result, classroom instruction and remediation efforts would benefit from including morphological instruction as part of their teaching. As Nunes et al. (2006) suggests, "Some of the most important correspondences between spoken and written language are at the level of the morpheme…The system of morphemes, therefore, is a powerful resource for those learning literacy" (p. 157).

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