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Preschoolers' Alphabet Learning:

Letter Name and Sound Instruction, Cognitive Processes, and English Proficiency

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Abstract

This study investigated: 1) the influence of alphabet instructional content (letter names, letter sounds, or both) on alphabet learning and engagement of English only and dual language learner (DLL) children, and 2) the relation between children's initial status and growth in three underlying cognitive learning processes (paired-associate, articulation referencing, and orthographic learning) and growth in alphabet learning. Subjects were 83 preschool children in six public preschool classrooms with low-income eligibility thresholds, including 30 DLLs. Children were screened for alphabet knowledge and randomly assigned to small groups and one of four conditions: experimental letter names or letter sounds only, experimental letter names+sounds (LN+LS), or typical LN+LS. Research assistants provided nine weeks of instruction in each treatment, in 10-minute sessions, four days/week. Irrespective of language status, children in the four groups made significant growth from pretest to posttest on measures of alphabet learning. The single-focus letter name or letter sound conditions led to significantly greater growth on taught alphabet content. The experimental LN+LS condition led to greater growth in taught letter names and sounds content compared to the typical LN+LS condition. Pretest vocabulary and alphabet knowledge did not moderate growth, and only limited evidence of differential response to instruction among DLLs was found. Paired associate and articulation referencing learning processes were related to alphabetic growth. Engagement during learning was high in all four treatments. Findings support the benefits of explicit alphabet instruction that enlists cognitive learning processes required for alphabet learning.

Keywords: alphabet, letter names and letter sounds, paired-associate learning, articulation, preschool

Preschoolers' Alphabet Learning:

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"It's as simple as ABC." This familiar adage captures the typical perception that children seem to effortlessly learn the associations between individual letter names and letter sounds, and their corresponding written letter. Yet task analyses of letter learning indicate that in actuality learning the alphabet letters is cognitively demanding (Ehri & Roberts, 2006; Foulin, 2005; Nilsen & Bourassa, 2008). Beginners must learn to distinguish non-representational shapes that may be very similar and to associate accurately these shapes with letter names and letter sounds that may also sound similar to each other.

Early acquisition of alphabet knowledge is important. Knowledge of the alphabet at kindergarten entry is one of the two best predictors of reading and spelling acquisition, including comprehension (Adams, 1990; Ball & Blachman, 1991; Bond & Dykstra, 1967; Chall, 1967; Foulin, 2005; McBride-Chang, 1999; Muter, Hulme, Snowling, & Stevenson, 2004; Piasta, Petcher, & Justice, 2012). Importantly, there is evidence that the relation between children's early alphabet knowledge and later literacy skills is likely causal (Ehri, 1987; Piasta & Wagner, 2010a; Roberts, 2003; Treiman & Kessler, 2003). Both accuracy and speed of letter identification is needed (Roberts, Christo, & Shefelbine, 2010). Yet several sources of evidence from both larger- and smaller-scale studies persuasively document that many preschool children are not achieving high levels of alphabetic knowledge as reflected in measures of letter name or sound accuracy.

In the USA, recent evaluations of Head Start (U.S. Department of Health and Human Services, 2005), multi-component preschool literacy curricula (PCERC, 2008), and the Early Reading First federal initiative (Gonzalez, Goetz, et al., 2011; Jackson et al., 2007), reveal mixed evidence of alphabet knowledge growth in accuracy. For example, children learned on average five letter names in one year of Head Start. Similarly, the PCERC found that only one of the 15 curricula tested improved children's letter/word performance at preschool. The number of letters (names or sounds) that children have learned, with learning construed as letter accuracy, from alphabetic instruction within individual studies has varied markedly from 4 to 23 or from 18% to 78% of the letters that were taught (Castles, Coltheart, Wilson, Valpied, & Wedgwood 2009; Diamond, Gerde, & Powell, 2008; Roberts 2003; U. S. Department of Education, Institute of Education Sciences, 2007; U. S. Department of Health and Human Services, 2005).

The nature of the alphabetic content has varied across studies of alphabetic instruction. Letter names (LN) have been taught, letter sounds (LS) or letter names + letter sounds (LN+LS) have been taught. Preschool teachers are uncertain about and keenly interested in which alphabet content they should teach (O'Leary, Cockburn, Powell, & Diamond, 2010). Scholars and even entire countries have debated the relative merits of teaching letter names and sounds (cf., Ellefson, Treiman, & Kessler, 2009; Levin et al., 2006).

Empirical investigation to determine the relative merits of teaching LN-Only, LS-Only, or LN+LS to preschool-age children becomes even more pressing in light of two facts. The first fact is that logical and theoretically plausible arguments can be given for the potential benefits of each of the three types of initial alphabet instruction content. The second fact is that there has been very limited research to determine which alphabet content may be most advantageous for gaining early alphabet knowledge.

We reviewed 12 randomized control trials (RCT) and quasi-experimental studies of preschool English alphabet instruction conducted in educational or clinic settings and found that only five investigated alphabet instruction alone, without phonological awareness instruction

(See Appendix). None compared letter name, letter sound, or letter name plus letter sound content within one study or examined both letter knowledge accuracy and speed. None disaggregated data based on whether children first learned English or a non-English language.[1]

Another characteristic of these studies is that linkages between instructional design and the cognitive learning processes (CLPs) most involved in learning to identify letters were not detailed. Missing information on instructional details prevented Piasta and Wagner (2010a) from analyzing the effectiveness of different instructional routines in their meta-analysis of alphabet instruction. These differences in the extent of alphabetic learning and the apparent limitations in theoretically-guided instructional design led us to conclude that alphabet instruction used in previous studies has not fully and consistently capitalized on underlying cognitive learning processes (CLPs) most strongly involved in alphabet learning. This state of affairs particularly merits remedying because small differences in instructional details affect early literacy learning (Byrne & Fielding-Barnsley, 1991; Connor, Morrison, & Slominski, 2006). The CLPs investigated in this study are paired associate learning (PAL), articulation-referencing learning (ARL), and orthographic learning (OL).

In this study we examine the relative merits of teaching letter names, letter sounds, or letter names+letter sounds with respect to speed and accuracy in letter identification and letter writing. We also examine the extent to which instruction that activates and extensively draws upon underlying cognitive learning processes influences learning of letter names and letter sounds and engagement compared to typical preschool instruction. Finally we consider how individual differences in cognitive learning processes enlisted in learning letter name/sound

[1] A child whose first language is not English is referred to as a dual language learner (DLL).

correspondences and language status that influence alphabetic learning. A mix of DLL and English only (EO) children were included.

To examine these questions preschool-age children were randomly assigned to one of four treatments. Three experimental treatments included different alphabet content (LN-Only, LS-Only, and LN+LS which we refer to as Experimental LN+LS to differentiate it from the fourth treatment) with instructional routines based on paired-associate learning, and the subcomponents of articulation-referencing learning, and orthographic learning. A fourth treatment based on classroom instruction typically used by preschool teachers was a treated control (Typical LN+LS). Measures of alphabet learning (letter name and sound identification, letter naming speed, letter and word spelling) were collected at pretest, midtest, and posttest and related to paired-associate learning, articulation-referencing learning, and orthographic learning competence. Children's engagement during learning was determined with observations of each child multiple times during instruction.

Optimal Content for Alphabet Instruction: Letter Names, Letter Sounds, or Letter Names + Letter Sounds?

Below we review theoretical arguments and existing evidence for the benefits of the three types of alphabet instruction content commonly enacted in preschool classrooms and compared in this study. Examining these three types of instruction in one study is a unique feature of this investigation. This theory and research guides our first research question.

Should we teach letter names? Young children typically know more letter names than letter sounds, but the source of the discrepancy is not known. U.S. children may have greater exposure to letter names than sounds. Letter names may also be easier to learn than sounds because of the fleeting and less distinctive nature of letter sounds and because letter names provide a whole-word verbal label for letter forms (Boyer & Ehri, 2011; Ehri & Roberts, 2006; Treiman & Kessler, 2003). Letter name instruction may also be advantageous for preschool-age children whose representations of individual English phonemes are still developing, and particularly so for DLLs who are learning the alphabet in a new language. Most letter names contain clues to their sounds (e.g., B-/b/, T-/t/), although a few do not (e.g., /y/ and /w/) (Treiman, Tincoff, Rodriguez, Mouzaki, & Francis, 1998; Treiman, Weatherston & Berch, 1994). Consequently preschool letter name instruction may lead to explicit letter name and implicit letter sound knowledge that may become available in phonological awareness, spelling, and word decoding tasks (Cardoso-Martins, Mesquita & Ehri, 2011; Ehri, 1986).

Should we teach letter sounds? Knowledge of letter sounds is more directly applicable to literacy skills such as phonological awareness, spelling and word decoding than letter name knowledge, suggesting instruction in letter sounds may be more beneficial to later authentic reading and spelling. The belief that letter sounds should be taught first is held so strongly in the United Kingdom that since 2007 their National Literacy Strategy stipulates that all children will first be taught letter sounds and synthetic phonics beginning at ages 4-5 (Department for Education, 2014; Rose, 2006). Concern has also been voiced that sounds may be preferred over names because letter names may actually introduce confusion to initial decoding and spelling because letter names map less well to sounds in words than do letter sounds. On the other hand, letter sound instruction may be particularly challenging for preschool DLL children whose mental representations of English phonemes are emerging or for those who may experience non-facilitating phoneme transfer from first to second language, and similarly for English first language preschool children with lower English language competence.

Should we teach letter names and letter sounds together? Eventually the vast majority of children acquire comprehensive knowledge of both letter names and sounds. However, teaching names and sounds together greatly increases the number of associations to be learned between visual letter forms and verbal letter labels, increasing task difficulty and potential for confusion between names and sounds. The confusability of letter names and sounds for young children is a very common occurrence (c.f., Piasta, Purpura, & Wagner, 2010). Teaching sounds and names together requires children to discriminate accurately between the labels for letter "names" and letter "sounds." These difficulties could be mitigated by concise and clear language, and sufficient and explicit emphasis on the distinction between letter names and letter sounds. Instruction in LN+LS would also logically require more instructional time for children to learn the increased number of associations between letter forms and both letter sound and letter name verbal labels, a challenge in light of preschool program time constraints. On the other hand, learning letter names and letter sounds at the same time may provide children with a distinctive amalgam for labeling letters (i.e. "F', /f/) and support integration of cognitive representations of names and sounds, leading to better memory for them.

Conceptualization of Learning and Instruction: Cognitive Learning Processes, Alphabet Knowledge, English Proficiency, and Engagement

The general conceptualization of learning and instruction guiding instructional design in the present study is that highly effective instruction explicitly engages the primary learning processes involved in learning alphabet content, activates these processes in multiple ways and across multiple occasions during learning, and creates conditions for learning that promote engagement. Task analyses of learning letter names and sounds (see McBride-Chang, 1999) indicate alphabet learning largely draws upon the primary cognitive process, visual-verbal paired associate learning (PAL). In addition to explicit activation of PAL and multiple and varied routines for utilization of PAL, our conceptualization of learning and instruction stipulates that learning and teaching routines to sharpen and draw upon both the verbal and the visual components of PAL individually should be beneficial. Therefore instruction exercises these two subcomponents of PAL. The verbal component of verbal-visual paired associate learning was targeted through an instructional routine based on speech articulation of letter names and letter sounds. This is referred to as articulation-referencing learning (ARL). The visual component of visual-verbal PAL was targeted through an instructional routine based on writing letters. This is referred to as orthographic learning (OL). Below we review the research and theory that guided the instructional design of each explicit alphabet condition and our second research question regarding the influence of engaging these cognitive processes on alphabet learning.

Paired associate learning (PAL). The importance of association learning in reading acquisition has been widely recognized (Castles, Coltheart, Wilson, Valpied, & Wedgwood, 2009; Hulme, Goetz, Gooch, Adams, & Snowling, 2007). Children's ability to form associations between printed symbols and verbal labels influences the acquisition of critical alphabet-related reading skills. (Hulme et al., 2007; Nilsen & Bourassa, 2008; Rey, Ziegler & Jacobs, 2000). Visual-verbal PAL contributes unique variance to early reading ability above and beyond that of other traditionally recognized skills such as phonological awareness (Hulme et al., 2007; Warmington & Hulme, 2012). Reading performance is correlated with visual-verbal PAL in both typically developing and children with reading difficulties (e.g., Hulme et al., 2007; Messbauer & de Jong, 2006; Windfuhr & Snowling, 2001). Individual differences in visual-verbal PAL are also observable in preschool- and kindergarten-age children (Apel et al., 2006; Hulme, et al., 2007; Ehri & Wright, 2007). In spite of the compelling evidence on the importance of PAL in reading, there has been little research with preschool children (see Hulme et al., 2007) and most alphabet instruction is not designed to explicitly promote PAL.

Articulation referencing learning (ARL). The motor theory of speech posits that articulatory gestures (the motor patterns that produce speech) rather than the sounds produced by them are the foundational elements of language in a first and second language (Flege, 1995; Liberman, 1999). The articulatory gestures embedded in speech input produce and interleave the phonemes in spoken words, and are recovered in the mind as phoneme abstractions. They are related to kindergarten and first-grade reading skills in DLLs (Roberts, 2005). Recent brain studies indicate that motor cortex and articulatory movements are involved in speech perception (D'Ausilio et al., 2009; Wilson, Saygin, Sereno, & Iacoboni, 2004). Measures of speech production accuracy index phonological representations in preschool children (Anthony, Aghara, Solari, Dunkelberger, Williams, & Liang, 2011). Explicit instruction that draws upon and potentially sharpens articulatory-based English phoneme representations is likely to be particularly beneficial to children whose phoneme representations may be less precise (Elbro, 1998; Mauer & Kahmi, 1996; Messbauer & de Jong, 2006). Alphabet instruction with an articulatory component may increase awareness and precision of articulatory gestures, and linkage of these gestures to letter sounds and names (Elbro, 1998).

Training studies drawing on or improving articulation have shown benefits for literacy for typically developing, language impaired, and disabled reader English-only children (Boyer & Ehri, 2011; Castiglioni-Spalten & Ehri, 2003; Gillon, 2005; Wise, Ring & Olson, 1999). Anticipated benefits of alphabet instruction with an articulatory component include increased awareness of articulatory gestures, linkage of these gestures to letter sounds and names, and bootstrapping learning of distinct phonological representations of letters that support later word reading and spelling (Anthony, Lonigan, Burgess, Driscoll, Phillips, & Cantor, 2002; Elbro, 1998; Wagner, Torgesen, Laughon, Simmons, & Rashotte, 1993).Enlisting ARL in alphabet instruction is expected to increase the efficiency of the PAL fundamental to letter identification by strengthening children's knowledge and memory of the verbal element of the pair.

Orthographic learning (OL). Paired-associate learning is related to orthographic learning, which is observed in young children when they form linkages between printed letters and their sounds (Wang, Wass, & Castles, 2017). The ability to process orthography is dependent upon reshaping of innate basic perceptual abilities to include an orthographic-specific visuo-perceptual processing ability (Dehaene, 2009). This reshaping occurs from encountering and learning about print. It is observable in preschool children and made a significant and independent contribution to spelling and reading (Apel, Thomas-Tate, Wilson-Fowler, & Brimo, 2012). Children from low SES families showed less skill in orthographic learning than more advantaged children (Apel et al., 2012), suggesting the value of determining if instruction that actively engages orthographic learning may promote alphabet learning in economically at-risk children. Preschoolers' ability to write individual letters is associated with their alphabet knowledge and phonemic awareness, and is more correlated with preschool and kindergarten literacy than is personal name writing (Diamond et al., 2008; Molfese et al., 2011). Yet letter writing has traditionally been seen as developmentally inappropriate for preschool children and is not often coordinated directly with preschool alphabet instruction (Vander Hart, Fitzpatrick, & Cortesa, 2010).

Recent research supports the value of the motor dimension of writing that creates cross-modal associative links between spelling and sound (Cunningham & Stanovich, 1990; Hulme & Bradley, 1984), with alphabet learning advantages accruing from this sensory integration that occurs during handwriting (Berninger et al., 2006; Longcamp et al., 2008). The motor dimension of writing creates cross-modal associative links between spelling and sound and sensory integration (Berninger et al., 2006; Hulme & Bradley, 1984). This evidence suggests that the verbal and visual cross-modal integration that occurs when learning to write letters paired is clearly paired with the letter name or letter sound label is likely to contribute to learning to recognize visual letters, the individual units of orthography (Rey et al., 2000). Letter writing is expected to increase the cross-modal PAL fundamental to letter identification by strengthening children's knowledge and memory of the graphemic element of the pair. Second, it is expected to promote spelling skill by developing the single-letter graphemic foundation supporting cross-modal orthographic learning of whole words (Castles, Wilson, & Coltheart, 2011) via instruction that helps children remember features of the written letters.

Alphabet knowledge. Alphabet knowledge is conceptualized to include both letter identification accuracy and letter identification speed. For novices, letter name accuracy may be the initial target but a very important application of alphabet knowledge is in learning to decode words, where the hallmark of skilled competence is accurate and fast word identification (Share, 2008). A recent meta-analysis of the role of rapid automatic naming which includes letter naming speed concluded that it was related to word identification of decodable, irregular words, and pseudowords from the very beginning of reading acquisition, and that alphanumeric rapid naming tasks, such as letter naming, show a particularly strong relationship with later word reading and comprehension skill (Araújo, Reis, Petersson, & Faísca, 2015). We sought to determine if this competence was discernible in preschool age children with very limited alphabet knowledge, and if letter naming speed was affected by the type of alphabet instruction in which children participated, in particular the treatments designed to draw heavily upon association learning.

English Proficiency

Conceptual rationale for how explicit instruction in alphabet content may sharpen phoneme representations to assist DLLs in learning the phonological distinctions amongst letter names and letter sounds and strengthen orthographic learning of individual letter forms were provided in the preceding discussion of alphabet content. In addition, many children from low-SES families, including many DLLs, enter and exit preschool with limited alphabet knowledge (Molfese, Beswick, Molnar, & Jacobi-Vessels, 2006; Scarborough, 1990). Strikingly, Spanish-speaking children were found to make no gains in letter knowledge after one year in Head Start (U.S. Department of Health and Human Services, 2005). The alphabet instruction reviewed by Piasta and Wagner (2010a) was not found to accelerate the alphabet learning of at-risk or DLL children. The increased vulnerability of children from low-income families and who speak a first language other than English to literacy under-achievement highlights the importance of carefully examining the relative merits of instructional variation in alphabet teaching for children from these two groups. Accordingly, the effectiveness of the theoretically derived instruction for DLLs was examined in the current study.

Engagement during Learning and Instruction

Engagement is related to acquisition of early literacy skills as early as preschool and kindergarten and the two are reciprocally related (Chang & Burns, 2005: Lepola, Poskiparta, Laakkonen & Niemi, 2005: see Morgan & Fuchs, 2007, for review). This reciprocal nature of learning and engagement (Chang & Burns, 2005; Ponitz & Rimm-Kaufmann, 2011) led us to develop instruction that explicitly included practices to support young children's engagement. A second reason for including instructional practices to support engagement is evidence indicating the potential for explicit instruction to decrease children's engagement in learning (Stipek, Daniels, Galluzzo, & Milburn, 1992; Stipek, Feiler, Daniels, & Milburn, 1995). Engagement was conceptualized to be a function of cognitive and affective constructs with the understanding that instructional practices interact and overlap across these two constructs. Attention deployment to learning targets and ensuring participation in learning routines are core practices supporting cognitive engagement. Identifying the goal of each lesson, employing simplified and clear language, and expecting choral and individual responding were specific practices included in instruction to effectively help children appropriately deploy attention and ensure high levels of participation. The alphabet content-oriented games, manipulatives, and opportunity for self-regulation included in instruction to support learning served the dual function of supporting children's positive affective experience. We conducted observation scans to examine differences in children's engagement within and across conditions.

In summary, the present study addresses two research questions: 1) what is the influence of instructional content (names, sounds, both) and nature of instructional practices on alphabet learning and engagement, and 2) what is the relation between growth in alphabet learning and initial status, and growth in underlying cognitive learning processes. We examined these questions in DLL and non-DLL preschool children. The brevity of the treatment, the difficulty in learning letters, children's status as novice alphabet-learners, and the theoretical interest in both initial status and change in CLPs all suggest focusing on growth in alphabet learning and growth in CLPs.

Method

Site Recruitment

Three elementary school sites were recruited in suburban districts near a western U.S. city. Each school had one full-day and two half-day (one am and pm) preschool classes with low-income eligibility thresholds for enrollment. The two half-day classes in each building were taught by the same regular teacher in the same classroom, and these classrooms had the same age-group distribution as the full-day classes. Under a memorandum of understanding with the school district, participating preschool teachers agreed to defer whole-class or small-group instruction on specific letters until after the intervention.

Sample and Random Assignment

Ninety-three children from six classrooms at three sites were initially enrolled and determined eligible for participation based on identifying fewer than four of the twelve letters to be taught on a screening task. Randomization, blocked by classroom and child language status, was performed by the first author. Language status – whether the child was English only (non-DLL) or dual language learner (DLL) was reported by parents at enrollment and confirmed by classroom teachers. Specifically, children were randomly assigned within classrooms into small groups of 3-5 students (averaging 4 per small group), and then randomly assigned to one of four conditions: letter names only (LN-Only), letter sounds only (LS-Only), letter names+sounds (Experimental LN+LS), or Typical LN+LS. Study attrition included six who moved prior to midtesting (2 LN-Only, 3 LS-Only, and 1 Experimental LN+LS). Four students in three classrooms had to be assigned to an out-of-classroom small group to ensure balanced small group sizes and were not included in analyses due to their cross-classified status (2 LN-Only, 1 LS-Only, and 1 Typical LN+LS). The final sample of 83 students in 24 small groups across six classrooms included 20 students in LN-Only, 18 students in LS-Only, 23 students in Experimental LN+LS, and 22 students in Typical LN+LS. There were 42 males, 41 females, and

30 children were DLLs. Age at pretest was *M* = 49.76 (*SD* = 5.11) months. Most of the children (83%) were from families whose incomes were less than 40% of the state median income.

Training

Testers (n = 8) and research assistant (RA) instructors (n = 3) included a former assessment coordinator, graduate students, and retired teachers. Testers and instructors each received a one-day, 8-hour training presented by the first author in the implementation of each the four conditions. Training emphasized the need to achieve high levels of response accuracy from the children by precisely articulating the letter sounds, adding explicit verbal models for DLLs, and monitoring student progress and providing corrective feedback. Prior to instruction RAs (instructors and assessors) spent 2-3 hours in the preschool classrooms in which they were assigned to teach or assess, meeting the children, and introducing procedures for transitioning into small groups and participating in activities during which they responded to questions.

Alphabet Content

Letters for instruction were chosen based on letter name pronunciation and ease of learning. Consonants included both acrophonic letters with letter sounds at the beginning of the letter name (*b, d, k, p, t*), and non-acrophonic letters (*f, n, m, s, h*). Letters included those typically learned early (a, b) and later (n, u) (Justice, Pence, Bowles, & Wiggins, 2006; McBride-Chang, 1999; Trieman et al., 1998). We also selected letters for ease of articulation by preschool children and DLLs (e.g., not v, z, j, l, or r). The 12 letters chosen for instruction were taught in this sequence: A, M, S, T, F, D, U, K, H, B, N, P. The reported district sequence of alphabet instruction during the intervention time period included nine of these 12 letters. All instruction and testing featured only upper-case letters, except that the Typical LN+LS condition saw lower case letters on the Alphafriends cards use to introduce letters (see below).

Experimental Alphabet Treatment Conditions

Weeks 1-6. Research team instructors implemented the same basic teaching activities for each of the three experimental alphabet treatment conditions (LN-Only, LS-Only, and LN+LS) and the typical instruction treatment. Order of lesson delivery alternated each day, with one RA delivering all four lesson types in each classroom. When a letter was introduced (e.g., "This is ___."), the instructor inserted the name, the sound, or the name plus sound, depending upon the treatment being implemented. As noted below, the number of repetitions was adjusted for the LN+LS condition so that letter repetitions and instructional time were similar across the three alphabet treatments.

Weeks 7-9. After a two-week break for individual student testing, the last three weeks of instruction provided intensive review for each of the 12 taught letters. One taught letter received special review each day, as well as daily cumulative review of all taught letters. Instructors emphasized that children carefully think about and attend to the printed letters and their sounds and/or names. The instructor added gestures for this thoughtful emphasis (pointing to their head) and reminded children of their important learning task. The lesson activities followed the same sequence as in weeks 1-6 with the following adaptations. Daily review featured all taught letters at the beginning of the lesson. Each letter taught in weeks 1-6 was highlighted for one day of review. Presentation of a model of the printed letter for the children to copy was followed asking children to write the letter from memory. During two discrimination trials, the children reviewed the letter of the day, mixed with two other letters. Finally, children chorally reviewed all taught letters, using their small spiral-bound alphabet books with one taught letter printed on each page. The instructor reinforced the thoughtful "reading" of these letters, and provided corrections when needed.

Detailed descriptions of all intervention protocols for each of the three experimental and the typical treatment conditions are provided in Online Resource 1.

Typical LN+LS Instruction

In the summer before the intervention, preschool teachers in the research sites were surveyed on the materials and approach they used on a regular basis to teach alphabet skills. Teachers provided information on: the frequency of lessons to teach each letter of the alphabet; the average length of lesson time; whether they taught upper- or lower-case letters or both; whether they taught letter names, sounds, or both; and whether they taught alphabet instruction in whole class or small group lessons, and to describe the activities they most frequently used. Teachers reported they most often used the Alphafriends cards (Houghton Mifflin, 2004) depicting a character with the target letter sound embedded in the name (e.g., Willy the Worm) with the upper- and lower-case letters displayed above the picture, and a poem about the character on the back of the card. Teachers reported they taught both letter names and sounds, and often used children's names, letter searches, and letter art activities. We used this information to structure the Typical LN+LS condition with lessons matched with the experimental instruction for time, small group size, and Monday-Thursday teaching schedule by trained research team teachers.

Measures

The norm-referenced PPVT measure was adapted for administration with young children with limited English. The language of the test instructions was simplified, and the pointing response needed to complete the task was modeled and enacted on practice items included to help children understand the task and response requirements. No change was made to any test items. At the end of each task children were given two training or test items, were provided correct answers as needed and praised. Testing average 45 minutes per child at each of the three testing occasions and were conducted over 2-4 sessions.

Prior to pretesting all students in the participating classrooms were screened on their knowledge of the 12 letters targeted for instruction. Students who knew more than four of the letter names to be taught were excluded from further testing and participation. Measures were individually administered in two blocks, with measures counterbalanced within blocks. English language proficiency and cognitive learning process tasks were also counterbalanced. Detail on assessment protocols is included in Online Resource 2.

English oral proficiency was measured with the IDEA Pre-IPT Oral Language Proficiency Test (Stevens, 2010), an age-appropriate assessment for children ages 3-5. It is designed to follow a story line with opportunities for oral interaction between tester and child. The test measures vocabulary, syntax, discourse and pragmatics to some degree. Proficiency levels range from A to E. Level A is Beginning (non-English speaking), Levels B and C are Intermediate, and Levels D and E are Advanced. Children are assigned a level from A-E based on performance scores that range from 0-42. Level A is non-English speaking (score of less than 5/10), levels B (score of 5-7/10) and C (score of 15- 17/ 20) are intermediate while levels D (score of 26-28/31) and E (scores of 37-42/42) indicate advanced English proficiency. Test-retest reliability of 0.77 is reported in the technical manual.

Receptive vocabulary was measured at pretest only with the norm-referenced *Peabody Picture Vocabulary Test-IIIA* (PPVT-IIIA; Dunn, & Dunn, 2006). The test was designed for ages 2.5 through 90 years. Students select a picture that best illustrates the meaning of an orally presented stimulus word. Testing is discontinued after the student misses 8 out of 12 items. Standard scores were used in analyses. For children ages 3-6, alpha coefficients reported in the manual range from 0.92 to 0.98, and test-retest reliability is reported to range from 0.92 to 0.94; validity, based on average correlations with measures of verbal ability are 0.91 (WISC-III VIQ), 0.87 (KAIT Crystallized IQ), and .82 (K-BIT Vocabulary).

Alphabet knowledge was tested with several measures. Letter name and sound knowledge were tested separately at each test point. The total score for each test was 26. Testers recorded student responses for taught (12) and untaught (14) letters, and the separate pretest scores for the taught letters are used in the models.

Taught and untaught letter names and letter sounds identification accuracy. At midtest and posttest children were tested with two smaller sets of taught and untaught letters only, for both names and sounds, and for both upper-case and lower-case letters. The orders in which these two sets of letters and sounds were tested were counterbalanced. Cronbach's alpha sample reliability of the letter names set and letter sounds set averaged 0.87, and 0.83 respectively.

Letter naming speed. Students were tested on naming the 12 taught letters. The upper case letters were printed on a sheet with the letters randomly arranged in four rows of six letters per row. The tester first presented a set of four practice (untaught) letters, modeling how to point and name each letter. Testers provided the correct name feedback if children could not name the practice items. No feedback or corrections were provided on the test items. The score was the total number of letters named correctly in 30 secs, with a maximum score of 24. Cronbach's alpha sample reliability averaged 0.95.

Letter writing/spelling. For the letter writing, the tester dictated the name and sound of a letter, asking the child to write the letter name/sound: "Write the letter (name/sound)." Four letters were tested: *t, a, b, m*. For the spelling test, the tester dictated a pseudoword and instructed the child to "write as many letters as you can." Then the tester modeled spelling the practice word *mat*, saying each letter name as the tester wrote the letter. The tester dictated four pseudoword items: *dap, hun*, *mab, sut*. All letters tested in letter writing and spelling were taught in the interventions. The score was one point for each letter written (maximum letter writing score of 4 points), and one point for each correct letter spelled (maximum spelling score of 12 points). A composite score was created for letter writing/spelling with a maximum score of 16 points. Cronbach's alpha sample reliability averaged 0.70.

Cognitive learning process (CLP) measures. The following CLP tasks were administered in a counterbalanced order.

Paired associate learning (PAL). The PAL task for the study was adapted from Hulme, Goetz, Gooch, Adams, and Snowling (2007), as further adapted by Litt and her colleagues (Litt, de Jong, van Bergen, & Nation, 2013; Litt & Nation, 2014). We obtained materials for paired associates from Dr. Robin Litt used in her work with 4-6 year olds and selected a subset of distinct visual symbols and pseudoword items, selecting symbol labels that presented minimal articulation difficulty for young children, including DLLs. The tasks included two sets (A and B) of three paired symbols and verbal labels tested counterbalanced across a visual-verbal and a verbal-visual task. In the visual-verbal task, stimuli were presented visually and a verbal response was required, while in the verbal-visual task, symbols were verbally named and a pointing response was required. Children were first taught the association between each written symbol and its spoken name in one teaching trial. Following the teaching trial there were five testing trials. For each visual-verbal testing trial, the tester shuffled the three symbol cards, and presented each card one at a time, pointing to and touching the symbol and asking "What name?" For each verbal-visual testing trial, the tester shuffled two sets of cards: one set of three cards with one symbol on each card and one set of three cards that contained all three symbols in different arrangements. The tester presented the first testing card with three pictures, quickly pointed to each picture on the card, said the label for the symbol, directed the child to the three-picture testing card and said "Touch the picture." The maximum score for each PAL task is 15. Sample reliabilities (Cronbach's alpha) for visual-verbal PAL at pretest, midtest, and posttest, averaged across Sets A and B, were 0.75, 0.87, and 0.86, respectively; and for verbal-visual PAL, reliabilities were 0.67, 0.67, and 0.55, respectively. A composite of the verbal-visual and visual-verbal tasks was used in analyses because differences in the extent to which visual-verbal and verbal-visual task demands relate to reading have been suggested.

*Articulation referencing learning (ARL)***.** Similar to the tasks used to teach correspondences between mouth pictures and phonemes by Boyer and Ehri (2011), the learning task we created used photographs of children's mouth shapes forming tested letter sounds. Two practice items (W, J) familiarized children with the task and responses. Test items featured pictures of mouth articulation for the letters: M, F, H, S, and T. Letters were chosen to represent a range of articulation movements. There were two practice trials and five learning trials. The maximum score is 25 points. Sample reliabilities (Cronbach's alpha) at pretest, midtest, and posttest were 0.91, 0.94, and 0.92, respectively.

Orthographic learning (OL). We obtained materials from the lead author (Kenn Apel) for the Orthographic Learning Measure (Mental Graphemic Representations) (Apel et al., 2006) previously used with 5-year-old preschool children. We adapted the task to include six pseudoword stimuli and stories including three pseudoword items with high phonotactic/high orthotactic characteristics (*hess, chan, sime*), and three pseudoword items with low phonotactic/high orthotactic characteristics (*chab, thug, gove*). The maximum score is 6 points. Sample reliabilities (Cronbach's alpha) at pretest, midtest, and posttest were 0.31, 0.00, and 0.05, respectively. Item difficulties were high, ranging from 0.12 – 0.22 at pretest (averaging 0.17) to 0.17 – 0.28 at posttest (averaging 0.24).

Child engagement. Behavioral engagement (attention, participation, affect) was rated during researchers' observations of lessons during weeks 3-4. Each child, selected in a random order, was observed for 10 seconds with attention, participation, and affect coded immediately thereafter. Three observations were made for each child during a lesson. Researchers recorded the specific lesson activity that the RA instructor was implementing during each 10-second scan. Each child's engagement behavior was rated with a 3-point rating (1 = high, 2 = medium, 3 = low). Anchors were specified for each behavior. Child attention and participation was rated as high, medium, or low on-task. Child participation was rated as high, medium, or low. Child affect was rated as mostly positive, mostly neutral, or mostly negative.

Child engagement observations were conducted by one research assistant with whom interrater reliability was established with the first author (n = 16) and one research assistant (n = 12). Interrater reliability was established at 99% on a sample of 6% of observations. Level of engagement observed was high in all four treatments, and averaged 1.04 (SD = 0.15) for LN-Only, 1.08 (SD = 0.29) for LS-Only, 1.03 (SD = 0.11) for LN+LS, and 1.11 (SD = 0.30) for Typical LN+LS.

Treatment integrity. The first author and two research assistants conducted onsite observations to establish rater coding reliability for correct treatment and lesson activities implementation , coding yes = 1 or no = 0 for whether the correct type of instruction and correct treatment activities were completed,. The observers also rated the quality of instructional delivery for all four conditions. Instructional delivery for all treatments was scored with a 5-point rating scale (1 = very low, to 5 = very high).

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Interrater agreement (percentage of exact matches between observers for a set of paired observations for each type of treatment) was high, at 100% for lesson activity components for each treatment. Observer agreements for instructional delivery components were 71% for LN-Only, 78% for LS-Only, 100% for LN+LS, and 93% for Typical LN+LS. Based on 40 observations across the three experimental alphabet treatment conditions, fidelity for lesson activities averaged 0.99 (out of 1.00); for instructional delivery, fidelity averaged 4.97 (out of 5.00). Based on 15 observations conducted for the Typical LS+LS condition, fidelity for lesson activities averaged 1.00 (out of 1.00), and for lesson delivery averaged 4.88 (out of 5.00).

Treatment intensity. The RAs instructors recorded student attendance. Complete attendance was missing for one school (21 students). Lesson attendance for 62 students from the other two schools averaged 35 sessions (*SD* = 0.70) out of a possible total of 36 lessons.

Data Analytic Approach

A multilevel modeling approach was adopted for data analyses (all models were estimated with maximum likelihood in *HLM7*). The reasons for this choice include: 1) the appropriate primary unit of analysis is the small group because students received instruction in one of four alphabet instruction conditions in small groups, 2) we would have flexibility in structuring the intervals of time between pretest, midtest, and posttest to accurately estimate student change over time, 3) and to account for teacher membership). The three theory-based conditions in which paired-associate learning and its subcomponents (ARL and OL) were emphasized are referred to as "experimental" conditions or treatments.

General data structure. Preliminary analyses were conducted to understand the hierarchical structure of the data with respect to students nested within their classes, within teachers and sites. Three of the six participating teachers taught two classes. Simple 2-group *t*-tests on each of our measures found no evidence of differences between the classes within a teacher (*p*s > 0.10); as such, all students taught by a given teacher were treated as being from that teacher. Site differences (recall that teachers were recruited from three preschools, with two teachers per site) were checked using three-level models (students within small groups within teachers) in which school membership was effect coded and tested as a set of teacher-level fixed effects. Only one difference was found: one site had higher pretest vocabulary (PPVT) than the others (*Coeff* = 11.02 points above average, $p = 0.029$). Since pretest vocabulary was already planned as being a covariate in our treatment effects models (as part of our theoretical rationale), site membership was dropped as a predictor from subsequent analyses.

We also examined the magnitude of nesting of student scores within small groups and teachers to help determine the hierarchical data structure. Specifically, intercept-only random effects models were used to estimate the magnitude of the intraclass correlation for each of the four outcomes (ICC; percent of variance each random effect accounts for in Level 1 scores), where students' scores were treated as Level 1 ($n = 83$), small groups as Level 2 ($n = 24$), and teachers as Level 3 ($n = 6$). Small group ICCs averaged 0.02 at pretest, 0.07 at midtest, and 0.11 at posttest, and teacher ICCs averaged 0.09at pretest, 0.06 at midtest, and 0.08 at posttest, which is consistent with ICC estimates found previously for kindergarten reading outcomes (cf., Hedges & Hedberg, 2007; Vadasy, Sanders, & Nelson, 2015).

Finally, recall that our research question regarding the effects of variation in alphabet content focuses on testing effects on students' *change over the course of instruction*, rather than at specific time points. As such, our growth models were specified as 4-level models, with measurements (three per student) as Level 1, students as Level 2, small groups as Level 3, and teachers as Level 4. Time was coded so that pretest was the intercept (0 months), midtest at 1.87 months since pretest, and posttest coded at 3.27 months since pretest (reflecting real time between measurements). Our general growth model with no covariates was as follows.

$$Score_{\mathrm{ijkl}} = \gamma_{0000} + \gamma_{1000}{*}Time_{\mathrm{jkl}}$$
$$+ U_{0\mathrm{jkl}} + U_{00\mathrm{kl}} + U_{000\mathrm{l}} + U_{1\mathrm{jkl}}{*}Time + U_{10\mathrm{kl}}{*}Time + U_{100\mathrm{l}}{*}Time + r_{\mathrm{ijkl}}.$$

In the model above, the *i*th score for the *j*th student in the *k*th small group and *l*th teacher is equal to the sum of: the mean pretest (γ_{0000}), the mean change per month over time (γ_{1000}), the residual errors on pretest due to student, small group, and teacher ($U_{0\mathrm{jkl}}$, $U_{00\mathrm{kl}}$, $U_{000\mathrm{l}}$), the residual errors on monthly change over time due to student, small group, and teacher ($U_{1\mathrm{jkl}}$, $U_{10\mathrm{kl}}$, $U_{100\mathrm{l}}$), and within-student residual error (r_{ijkl}).

Final models. Given our preliminary analysis findings, a series of three multilevel models were used to test our research question regarding relative merits of LN-Only, LS-Only and Typical and Experimental Names + Sounds instruction. Each of these models accounted for students' small group and teacher membership random effects, as well as students' language status (effect coded as +1 = DLL and –1 = non-DLL), baseline PPVT vocabulary, and total letter names pretest knowledge (standardized in *z*-scores), as fixed effects.

- *Model 1*: The first model described *general growth trajectories* for each treatment and for DLL status, controlling for pretest vocabulary and alphabet knowledge on the four outcomes as well as the three cognitive processes. Treatments were effect coded into a set of three predictors at the small-group level (Level 3) with Typical LN+LS as the reference category.
- *Model 2*: The second model tested for *pairwise differences* among treatments (with four conditions, there are six comparisons) on growth over time, controlling for DLL status AND pretest vocabulary and alphabet knowledge. One treatment in each pair was effect coded in the positive direction and the second in the negative (e.g., for LN-Only vs. LS-Only, LN-Only was coded +1 and LS-Only was coded –1, and so forth).
- *Model 3*: The third model explored the contribution of growth in the three cognitive processes on growth in each of the four outcomes across treatments, but still controlling for DLL status and pretest vocabulary and alphabet knowledge. A three-step approach was used: 1) linear change over time per month was estimated for each of the three process measures using a 4-level model that did not control for any other variables, 2) the individual student predicted growth rate estimates were extracted from the *HLM7* growth models, and 3) the estimated individual rates were standardized (*z*-scores) and used as student-level predictors (Level 2) of growth over time for each of the four outcomes.

Adjusted alpha level for pairwise comparisons (Model 2). To avoid inflating Type I error due to multiple group comparisons on growth, we employ a Dunn-Sidak (DS) *p*-value adjustment. With a desired Experimentwise Type I error rate of 0.05 and $m = 6$ comparisons, our per-comparison *p*-value threshold for significance is 0.0085, rather than 0.05. For reader interest, observed (unadjusted) *p*-values are reported, and boldface used to indicate when a finding is statistically significant after adjustment.

Approximate effect size for pairwise comparisons (Model 2). For pairwise comparisons, we computed and report the *approximate* difference between any two conditions using *d** (determined by dividing the model-estimated treatment effect coefficient by the pooled approximate pooled standard deviation), interpreted as number of standard deviations difference in growth rate between the two conditions. The pooled approximate standard deviation was computed as the estimated standard error (*SE*) divided by the square root of the sum of the inverses of the treatment condition sizes (i.e., $SE \div \sqrt{[(1/n_1)+(1/n_2)]}$, an algebraic rearrangement of the 2-group *t*-test formula for computing the standard error with the pooled variance.

Results

Descriptive Statistics and Pretests

Table 1 displays sample descriptive statistics. The sample averaged M = 77.13 (SD = 20.84) on the norm-referenced (age-adjusted) standard score of the Peabody Picture Vocabulary Test-IIIA (PPVT), which translates to rank below the 10th percentile nationally. Differences between conditions on all pretest measures were checked, using three-level models (student scores within small groups within teachers; three effect-coded predictors represented the treatments, with Typical LN+LS as reference category). There were no differences among conditions on any pretest measure, nor proportions of students who were dual language learners (DLL) (using Bernoulli distribution for this last model); all coefficient test p-values > 0.05. Zero-order correlations for the combined conditions are provided in Table 2 (but we note that these correlations are not adjusted for dependencies in the data).

Model 1: General Growth Trajectories: Alphabet Outcomes

Table 3 reports the mean growth trajectories by condition, controlling for DLL status, pretest vocabulary and alphabet knowledge, for the four alphabet learning outcomes.

Pretest. The intercept (i.e., mean pretest score) was close to zero for alphabet outcomes (*Coeff* = 0.47, 0.69, 0.13, and 0.13 for letter naming speed, taught letter names, taught letter sounds, and writing/ spelling, respectively), holding all other predictors constant. There were no statistically significant effects on pretests due to condition, DLL status, or pretest vocabulary. Total letter names known at pretest (alphabet knowledge) was correlated with pretest letter naming speed, taught letter names, and writing/spelling.

Mean Growth. The mean estimated monthly growth rate from pretest to posttest, irrespective of condition, was statistically significant for all four outcomes, with rates of 1.18, 0.97, 0.85, and 0.41 letters /month gained for letter naming speed, taught letter names, taught letter sounds, and writing/spelling, respectively. Over a three-month period, students were estimated to have gained an average of 3.54, 2.91, 2.55, and 1.23 letters on these measures, holding all else constant). There were possible scores of 26, 12, 12, and 16, on these measures; thus students were predicted to gain approximately 14% on letter naming speed, 24% on taught letter names, 21% on taught letter sounds, and 8% on writing/spelling from pretest to posttest.

Treatment Condition Effects on Mean Growth. For Model 1, the effect of condition on *mean* pretest and growth simultaneously was tested using all conditions to generate the growth estimates. The four condition categories (LN-Only, LS-Only, Experimental LN+LS, and Typical LN+LS) were represented as a set of three effect-coded predictors. One category must become the reference category, which in this case was the Typical LN+LS condition. Each treatment condition's effect on growth was compared to *mean growth*, except for the control category, which was not directly tested in the model (forthcoming pairwise comparison models compare all pairs of conditions with each other). Nevertheless, we can compute predicted values for all four conditions at each time point using this model's estimates. To obtain LN-Only's predicted values, we would multiply +1 with the coefficient estimates for LN-Only effects on pretest and growth, and multiply 0 with each of the other conditions' coefficient estimates. The same process was used for LS-Only and Experimental LN+LS effects on pretest and growth. Finally, because Typical LN+LS was the control category and we used effect coding, we multiplied -1 with each of the other conditions' coefficient estimates for both pretest and growth to obtain this condition's predicted values.

Table 3 shows that the LN-Only condition was found to have a statistically significant positive effect on *mean* growth for both letter names outcomes (0.70 and 1.14 more letters per month than the mean growth rates on taught letter names and letter naming speed, respectively) whereas the LS-Only condition was statistically significantly lower than *mean* growth in these outcomes (0.89 and 1.04 fewer letters per month than *mean* growth, respectively). In addition, the Experimental LN+LS condition had significantly greater growth than average growth on both taught letter names and taught letter sounds (0.37 and 0.33 points per month more growth than average, respectively). Figure 1 illustrates the model-predicted trajectories for each condition by outcome.

DLL Effects on Mean Growth. DLL students did not differ in their growth rates from non-DLL students on any of the alphabet outcomes (see Figure 2 for model-predicted trajectories); however, our models controlled for pretest vocabulary and alphabet knowledge. As a check on this finding, first, we conducted post-hoc three-level models to test for DLL and non-DLL differences on pretests and found that DLL students were 27.57 points (SE = 3.01) lower than non-DLL peers on pretest receptive vocabulary ($p < 0.001$) and 1.58 letters (SE = 0.57) lower on pretest alphabet knowledge ($p = 0.008$). Second, we re-ran our growth models without controlling for pretest vocabulary or alphabet knowledge and found that DLLs had significantly lower monthly growth rates than non-DLL peers on taught letter sounds and writing/spelling (by 0.56 and 0.32 letters per month, respectively; *p*s < 0.05). Finally, we tested whether treatment condition effects on growth were moderated by DLL status (again, not controlling for pretest vocabulary or alphabet knowledge). Results showed no interactions (all *p*s > 0.05), which was also true when pretest vocabulary and alphabet knowledge were re-introduced back into the model). In other words, although DLLs had lower growth than non-DLLs on two of the alphabet outcomes when pretest levels were not controlled for, DLL status did not moderate treatment condition effects on growth rates.

Model 2: Pairwise Differences among Treatment Conditions on Growth

The second (and focal) set of models tested the effects of treatment using pairwise comparisons on alphabet growth from pretest to posttest (Table 4). Observed *p*-values that are statistically significant after adjustment (Dunn-Sidak adjusted *p*-value for significance is .0085) are presented in boldface. LN-Only had significantly higher growth than LS-Only on both letter names measures (estimated at 1.48 and 2.08 and points greater growth on taught letter names (accuracy) and letter naming speed, respectively; double the coefficient due to effect coding used), but lower growth on taught letter sounds (estimated difference of 0.66 points, all else held constant). LN-Only was also superior on growth for both letter naming accuracy and speed when compared to Typical LN+LS instruction, but not for taught letter sounds or writing/spelling.

Experimental LN+LS was similarly significantly higher than LS-Only on growth on both letter name measures by 1.26 letters (taught letter names) and 1.32 letters (letter naming speed). There was no evidence of a difference on growth for taught letter sounds. Further, when Experimental LN+LS was compared with Typical LN+LS, there was a statistically significant unique effect on growth for taught letter sounds (0.66 points better for Experimental LN+LS).

Finally, we found that LS-Only did not differ from Typical LN+LS instruction on any alphabet outcome.

Overall, both LN-Only and Experimental LN+LS conditions had reliable advantages for increasing growth in both accuracy and speed of letter name identification compared to the LS-Only condition. The LN-only condition was superior for both letter name measures compared to Typical LN+LS conditions. Experimental LN+LS condition was superior for letter sound identification growth compared to the Typical LN+LS condition.

Model 3: Contribution of Cognitive Processes Growth to Alphabet Growth

We explored whether growth on the CLP measures might correlate with growth on the alphabet outcomes, controlling for DLL status as well as pretest vocabulary and letter name knowledge. Four-level growth model results, given in Table 5, show that growth in PAL was significantly related to letter name outcomes, controlling for the other CLP growth rates. For every standard deviation increase in PAL growth, there was an estimated increase of 0.48 and 0.38 points letters per month in letter naming speed and taught letter name accuracy, respectively, holding all else constant. Further, growth in ARL was significantly and uniquely related to taught letter names and writing/spelling. For every standard deviation increase in ARL growth rate, there was an estimated 0.24 and 0.14 points per month related increase in these alphabet outcomes, respectively.

Exploratory Models: Correlates of Growth in Cognitive Processes

As can be seen in Table 2, simple correlations (not accounting for nesting structure of data) among pretest CLP scores and posttest alphabet learning measures were modest (ranging from 0.13 to 0.32) but reliable for pretest PAL and AL with posttest letter naming and letter writing/spelling (but not letter sounds).

Although not tabled due to page constraints, we explored children's growth on the CLP measures using the same procedures as our outcome measures and found that monthly growth rates for PAL and ARL were significantly greater than zero at 2.18 and 2.37 points per month, respectively. Mean growth for OL on the other hand was estimated at 0.13 points per month, which was not significantly different from zero. Across all three CLP models, DLL status and pretest alphabet knowledge did not predict growth, and there was one small, negative effect of pretest vocabulary on OL growth ($p < 0.05$). We further explored whether DLLs would differ from non-DLL peers on CLP growth rates if both pretest vocabulary and alphabet knowledge were dropped from the model but again found no statistically significant effects (ps > 0.05).

Discussion

The study shows that preschool children, including DLLs and children whose first language is English, can initiate positive growth trajectories for learning letter names and letter sounds and positive engagement during letter learning with approximately 6 hours of instruction distributed over a nine-week learning period. A nuanced and complex pattern of effects emerged indicating that initial alphabet learning is influenced by several factors. These factors include the content that is taught, the conceptualization of learning and instruction upon which the instruction is based, the breadth and depth of learning, and English proficiency. We were able to detect these patterns within one study in which 1) letter name, letter sound, and letter names + sounds content was compared, 2) a cognitive science based model of instruction was compared with instructional routines typically used by preschool teachers, 3) the growth trajectories of DLLs and children whose first language was English were disaggregated, and 4) both accuracy and speed of letter identification were measured. We discuss these nuances and complexities in the context of the research focus identified in the introduction: content of alphabet instruction, the conceptualization of alphabet learning and instruction based on cognitive learning processes, findings for DLLs, and children's engagement during learning.

Content of Alphabet Instruction

Children in all four conditions that included explicit and letter-focused instruction experienced, on average, statistically significant growth from pretest to posttest on all four measures of alphabet learning: letter name identification accuracy and speed, letter sound identification, and writing/spelling. Synthesizing the results for treatment variation, we find there is no simple answer to the question, "What is the most efficacious alphabet content to teach to preschool children?" Both Experimental LN + LS and LN-only conditions led to statistically significant advantages on growth in alphabet learning, with these advantages dependent upon whether breadth as represented by accurate letter identification or depth as represented by letter naming speed is focused upon, and specific treatment comparisons.

Experimental LN+ LS instruction shows promise as being advantageous for breadth of letter name and letter sound learning. In the general growth model, Experimental LN+LS instruction resulted in greater than mean growth in both letter name and letter sound identification. Pairwise comparisons for letter sound identification showed that Experimental LN+LS instruction led to greater growth than Typical LN+LS instruction, and had growth not different from that of LS-Only instruction. Pairwise comparisons for letter name identification revealed that Experimental LN+LS instruction had significantly greater growth than LS-Only instruction on both letter name measures, and no difference with single-focus LN-Only instruction on both letter name measures. The associated effect sizes were large to very large, with group differences in mean growth rates ranging from 0.83 to 1.62 standard deviations, based on d^* approximate effect size computations. Average effect sizes reported in the Piasta and Wagner (2010) meta-analysis for alphabet instruction were .14 for letter names, .48 for letter sounds and .64 for names + sounds. This breadth advantage can be inferred by looking at the posttest composite of correct letter name *and* letter sound identification for each treatment group: Experimental LN+LS = 9.65 total letters, Typical LN+LS = 6.09 total letters, LN-Only = 7.00 total letters, LS-Only = 4.61 total letters (see Table 1). We emphasize that the combined letter name and letter sound instruction led to greater growth when it was coupled with intensive PAL, including its ARL and OL components. Scores on the five acrophonic and the four non-acrophonic letters were coded for each child to see if letter names might lay a foundation for letter sound learning. We reasoned that letter names containing the letter sound at the beginning (e.g., B, P, T, D, K) should predict greater growth than those containing the letter sound at the end (e.g., F, N, M, S) if letter name learning boosted letter sound learning. Multilevel models revealed no such evidence. Direct teaching of letter sounds seems to be necessary for developing letter sound knowledge, a knowledge critical for learning to read words.

Speculative interpretations for results suggesting the benefit of LN + LS instruction include potential memory advantages from the distinctive and salient name + sound labels that were attached to each letter form (i.e. "f", /f/) and the integrated cognitive representations of letter names and letter sounds when they are taught together. The potential to contrast letter names and letter sounds when they were taught together may have helped establish clarity between the two, similar to the well-established principle of the benefit of contrastive examples in concept formation. Perhaps the simple explanation that more challenging content exposure leads to more learning as reported for kindergarten (Claessens, Engel, & Curran, 2014) is apt, with the caveat that high-quality instruction such as occurred in the experimental treatments emphasizing paired associate learning is necessary to enable the learning.

On the other hand, LN-Only instruction resulted in significantly greater growth on both accurate identification and letter naming speed. This significantly greater growth was found in comparison to mean growth rate across conditions and in pairwise comparisons to the LS-only and Typical LN+LS instruction that included less intensive letter name instruction, and was absent the focus on cognitive learning processes. We take this to indicate that LN-Only instruction was particularly effective in promoting growth in depth of letter name knowledge because speeded letter identification is dependent upon well-established letter familiarity. The associated effect sizes were large to very large, with group differences in mean growth rates ranging from 0.95 to 1.87 standard deviations, based on *d** approximate effect size computations. Single focus letter instruction (either LN- or LS-Only) led to significantly greater growth only on their respective taught alphabet content (letter names or letter sounds).

Letter sound alphabet content appears to be more difficult to learn than letter name content for English only children and DLLs. Several results indicate this difficulty. LS-Only instruction did not lead to better than average letter sound identification growth. LS-Only instruction was not better for letter sound learning than Experimental or Typical LN+LS instruction, both of which included a smaller dosage of letter sound instruction. The treatment that focused solely on letter sound learning produced significantly greater growth only in comparison to the treatment in which there was *no* letter sound instruction, LN-Only. Finally, overall DLLs had significantly lower letter sound growth than English only children in the model in which there were no covariates. The study does not yield any direct evidence for why letter sound learning may be more difficult than letter name learning. Our theoretical analysis of letter sound learning in the introduction identified a number of features of letter sound learning that may make it more difficult. These features largely implicate the single-phoneme nature of letter sounds, and are discussed in more detail in the section on English language proficiency.

Conceptual Framework for Learning and Instruction

The study design was based upon the assumption that instruction drawing upon and exercising task-specific, cognitive learning processes involved in alphabetic learning would lead to better letter learning than other instruction. The examination of this expectation was accomplished by focusing on the effects of instruction and by conducting an exploratory investigation of the relationship of individual differences in initial status and growth in cognitive learning processes to letter learning for both DLL and non-DLL children. We also anticipated that high levels of engagement would support letter learning because of the reciprocal nature of literacy learning and engagement.

Instruction comparisons. The clearest illustration of the superiority of experimental instruction extensively drawing upon PAL, ARL, and OL cognitive learning processes was observed in the comparison of Experimental LN+LS to Typical LN+LS, where the letter content of instruction, but not instructional routines, is held constant. As already reviewed, in Model 1 this comparison revealed superiority for the Experimental LN+LS condition on letter name identification and letter sound identification, while in the pairwise comparisons of Model 2 the effect was present for letter sound identification only. This superiority for letter sound identification in the Experimental LN+LS condition is noteworthy given the overall pattern that letter sound identification was more difficult to learn than letter name identification, and that DLLs experienced significantly less growth on letter sounds than did English only children in models without covariates.

Additional evidence for the effectiveness of the experimental instruction is the benefit of single-focus letter name instruction for the letter name content that was taught (letter name identification, letter naming speed) in comparison to Typical LN+LS instruction. Typical instruction included common practices used by preschool teachers in alphabetic instruction, but did not include equivalent focused and explicit instructional routines to extensively exercise the PAL, OL and ARL cognitive learning processes hypothesized to be relied upon in alphabetic learning. Some degree of PAL learning was obligatory in the typical lessons, as it would be in any instruction in which letter labels (names, sounds) are paired with letter forms, and was most strongly prompted in letter introduction and review routines in typical instruction. It is also plausible that letter art activities drew attention to motoric and procedural processes of placing beans, and that searching for letters in personal names drew attention to social dimensions of personal names. The poems are likely to have required substantial allocation of attention to semantic understanding of unusual vocabulary and narrative structures. The large Alphafriend image is likely to have drawn children's attention to the pictures rather than letters, particularly since the image and the letter forms were not integrated (Both-de Vries, & Bus, 2014; Ehri, Deffner, & Wilce, 1984)). Typical instruction was not significantly better than any of the three experimental instruction conditions on the three pairwise comparisons performed for each of the four alphabet knowledge outcomes.

Cognitive learning processes. We explored the relationship of cognitive learning processes measured at pretest and posttest on alphabet learning growth. Children experienced statistically significant growth from pretest to posttest in two of the three cognitive learning processes (those that were most reliably measured: PAL and ARL) embedded in instruction. This growth was detected after a brief nine weeks of instruction. An approximate increase of 90% in

ARL scores, 70% in PAL scores, and 45% percent in OL scores was observed. It is not possible to determine to what extent this growth may be a function of shared experience in alphabet learning, general development, learning to do the tasks over three testings, or a combination of these alternatives. Correlations between pretest CLP scores and posttest alphabetic scores show that initial status, as well as growth, in CLPs in preschool-age children just beginning to learn letters is related to subsequent alphabetic learning.

Relationships among PAL and its ARL subcomponent, and alphabet learning provide support for the conceptualization that these cognitive processes are involved in alphabet learning. Growth in PAL and ARL were related to letter name identification. In addition, growth in paired associate learning (PAL) was significantly related to growth on both accuracy and speed of naming taught letters. Articulation-referencing learning (ARL) was significantly related to growth in accurately naming taught letters. In addition, growth in ARL was significantly related to growth in letter writing/spelling. CLPs were not related to letter sound growth. Relationships among learning to articulate English phonemes, growth in letter name identification, and writing may be detectable for taught letter names before taught letter sounds because developmentally children's letter name knowledge is typically in advance of their letter sound knowledge.

The limited relationship of the orthographic learning (OL) measure to alphabetic learning and in particular letter writing/spelling, the poor reliability of the measure, and limited growth in OL likely reflect the difficulty of the task. Alternatively, the short 9-week exposure to brief 10-minute lessons Monday through Thursday may not have been sufficient to develop orthographic sensitivity to a level tested in the OL task, consistent with other studies suggesting a slower course for orthographic learning that is more evident beginning in kindergarten after some exposure to printed letters (e.g., Apel et al., 2006). There were also no effects of treatment on letter writing/spelling, a task on which children had limited performance. An easier task in which letter writing was more scaffolded such as letter tracing may have been beneficial.

Alphabet Knowledge. Within our conceptual framework of learning and instruction, we distinguished between letter naming accuracy and letter naming speed. Letter naming speed reflects a level of alphabet knowledge that is theoretically and empirically more closely related to learning to decode words than is letter naming accuracy, presumably because it supports the automaticity needed for skilled word reading (Share, 2008; Roberts, Christo & Shefelbine, 2010). The results show that single focus LN-Only instruction significantly influenced growth on rapid letter name identification more extensively than did other treatments. This treatment contained more PAL, ARL and OL for letter names than any other instruction. This treatment-specific finding supports the claim that accuracy and speed outcomes of early letter instruction are detectable in preschool children, and the present study gives a nod toward LN-Only instruction for promoting both most strongly. This finding is significant because of the importance of rapid naming in learning to read words (Araújo et al., 2015). We note that measures of rapid letter naming show this relationship in spite of the direct applicability of letter sounds to learning to read words.

English Proficiency. The DLL children entered with substantially lower levels of receptive vocabulary (standard scores averaging in the lower 10% nationally) and lower total alphabet letter-name knowledge than the English only children. Yet, DLLs were indeed capable of learning letters and showed growth in cognitive learning processes at the same rate of growth as English fluent children when controlling for pretest vocabulary and pretest alphabet knowledge. However, with those covariates dropped from the model, DLL students had a statistically significant lower growth rate on taught letter sounds and writing/spelling. For DLLs, letter sounds were more difficult to learn than other alphabet content, with English vocabulary and alphabet knowledge at preschool entry being implicated in the disparity. The disparity was found even when great care had been taken to develop instructional activities and instructional language that would ensure DLLs could access the letter sound learning hoped for. The finding for letter sounds is consistent with the a priori analysis that English phoneme representations may be less distinctive, accurate, or sharp for DLLs, leading to difficulty in remembering the frequently subtle phonological distinctions required in learning letter sounds - whose spoken production is very brief and unlike real words (Anthony et al., 2011).

Engagement during Learning and Instruction. The observation scans to determine children's engagement were very high across all of the treatment conditions, including typical instruction. Because of this ceiling effect, multilevel models of instruction and engagement were not estimated. Nevertheless, the observation scans indicated that children's engagement during explicit and letter-focused instruction was characterized as showing high attention and participation, and positive affect in each type of explicit instruction in letter names or letter sounds. The means were similarly high for DLL and non-DLL children. It is encouraging that teaching practices intentionally designed to promote both cognitive learning and positive engagement -- including extensive activation of PAL processes, simplified and clear language, choral and individual responding, alphabet oriented games, manipulatives, and opportunity for self-regulation -- can be effective.

Limitations and Future Directions

The present study was designed with the initial low levels of alphabet knowledge and the limited English proficiency characteristic of many children in public funded preschool programs in mind. Findings are therefore generalizable to preschool DLL and non-DLL children from lower-income backgrounds with limited early literacy skills similar to those in the sample. Children learned only about half of letters taught on the more cognitively demanding measure of oral letter *identification* (compared to letter *recognition)* in about six hours of instruction for twelve letters. A measure of rapid *sound* naming would have captured letter sound naming speed thereby permitting determination of the effects of treatment for both letter name and letter sound accuracy and speed.

Another issue in the present study is that we relied on customized measures that targeted taught content rather than knowledge that is more transferrable. Additionally, one of our process measures (OL) lacked a desired level of measurement reliability, rendering results unreliable. As such, future research should employ an adapted measure to better capture OL.

An additional issue is the power limitations we had for detecting effects. If we had tested treatment effects with a larger sample of small groups (since treatment was small-group oriented), we may have detected additional treatment effects. The present study had approximately 80% power to detect effect sizes of $d^* = 0.70$ or greater only. Nevertheless, we found eight such large effects that provide empirical evidence related to our key research question regarding the relative benefits of the teaching letter names, letter sounds or letter names+letter sounds.

Lastly, it was also not possible to determine the independent effectiveness of the PAL-, ARL-, and OL-loaded learning routines in the current study. A new study is underway to estimate independent contributions of each of these elements of instruction. The benefits of instruction were found on proximal alphabet outcomes with no test of the extent to which different types of alphabet instruction content (LS-Only, LN-Only, Experimental or Typical

LN+LS) may have influenced learning to decode words, a very important skill for the application of letter knowledge.

Summary and Conclusions

The results from the study show the benefits to learning the alphabet of aligning cognitive and instructional science (Seidenberg, 2013). Novel findings regarding the relative merits of teaching different alphabet content were detected. Instruction based upon cognitive processes central to alphabetic learning was more effective than other instruction. Letter name-only and Experimental LN+LS instruction were suggested as providing unique benefits to depth and breadth of alphabet letter learning, with Experimental LN +LS having the merit of efficiency. Preschool-age children had the capacity to do a great deal of the visual-verbal paired-associate learning required to learn letter names and letter sounds when they participated in explicit instruction providing multiple opportunities for practice in a variety of simple and letter-focused participatory and manipulative activities. Instruction in specific alphabet content was necessary for children to learn that content. There was evidence that both initial status and growth in PAL and ARL cognitive processes were related to alphabet learning in preschool-age children. All four types of explicit alphabet instruction were associated with high levels of engagement during instruction. Educators can be encouraged to use the type of letter name instruction described in this study with similar children who are learning English as a second language as well as those for whom English is their first language, with the expectation that it will be beneficial to children in each group.

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Table 1. *Sample Descriptive Statistics*

		Pretest		Midtest		Posttest	
Measure	*N*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*
Pretest Only							
PPVT-IIIA (0-204 points)							
LN-Only	20	23.75	(20.51)	--		--	
LS-Only	18	34.28	(22.38)	--		--	
Exp LN+LS	23	33.36	(18.40)	--		--	
Typ LN+LS	22	31.05	(18.76)	--		--	
Total Letter Name Acc (0-26 points)							
LN-Only	20	1.25	(2.17)	--		--	
LS-Only	18	1.28	(2.16)	--		--	
Exp LN+LS	23	2.43	(2.52)	--		--	
Typ LN+LS	22	2.82	(3.57)	--		--	
Alphabet Outcomes							
Letter Naming Speed/Minute (0-26 points or more—timed test)							
LN-Only	20	0.35	(0.81)	4.05	(4.97)	7.05	(7.05)
LS-Only	18	0.33	(1.19)	0.72	(1.87)	0.56	(1.25)
Exp LN+LS	23	0.70	(0.93)	1.91	(2.50)	5.35	(4.85)
Typ LN+LS	22	0.82	(1.59)	2.59	(2.92)	4.23	(4.95)
Taught Letter Names (0-12 points)							
LN-Only	20	0.60	(1.14)	3.40	(3.83)	5.55	(4.01)
LS-Only	18	0.50	(1.04)	0.72	(1.71)	0.67	(1.71)
Exp LN+LS	23	0.74	(0.92)	2.83	(2.99)	5.30	(3.52)
Typ LN+LS	22	1.05	(1.73)	2.36	(2.56)	3.86	(3.47)
Taught Letter Sounds (0-12 points)							
LN-Only	20	0.10	(0.31)	0.70	(1.08)	1.45	(2.33)
LS-Only	18	0.11	(0.32)	1.72	(1.90)	3.94	(2.44)
Exp LN+LS	23	0.35	(0.83)	2.78	(3.22)	4.35	(3.52)
Typ LN+LS	22	0.18	(0.50)	0.82	(1.18)	2.23	(2.76)
Writing/spelling (0-16 points)							
LN-Only	20	0.10	(0.45)	1.05	(1.50)	1.05	(1.36)
LS-Only	18	0.17	(0.71)	0.56	(1.10)	1.00	(1.19)
Exp LN+LS	23	0.26	(0.45)	1.17	(1.70)	2.04	(2.14)
Typ LN+LS	22	0.05	(0.21)	0.45	(0.96)	1.82	(2.24)

(continued)

Table 1. *Sample Descriptive Statistics, Continued*

		Pretest		Midtest		Posttest	
Measure	*N*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*
Cognitive Learning Process (CLP) Measures							
Paired Assoc Learning (PAL) (0-30 points)							
LN-Only	20	9.40	(5.77)	14.80	(5.25)	16.25	(6.28)
LS-Only	18	7.72	(6.00)	13.44	(5.15)	13.44	(5.47)
Exp LN+LS	23	9.00	(5.44)	13.43	(5.39)	15.70	(5.50)
Typ LN+LS	22	8.64	(4.39)	15.91	(6.91)	16.50	(7.10)
Articulatory Ref Learning (ARL) (0-25 points)							
LN-Only	20	9.10	(6.36)	13.15	(7.22)	16.20	(6.04)
LS-Only	18	5.50	(4.45)	9.39	(6.70)	12.06	(6.07)
Exp LN+LS	23	6.55	(4.55)	11.65	(7.31)	15.78	(5.97)
Typ LN+LS	22	7.45	(6.52)	13.41	(6.19)	14.41	(7.51)
Orthographic Learning (OL) (0-6 points)							
LN-Only	20	0.80	(0.89)	1.15	(0.88)	1.30	(1.03)
LS-Only	18	1.00	(1.28)	1.61	(1.46)	1.56	(1.10)
Exp LN+LS	23	1.09	(1.08)	1.13	(0.55)	1.43	(1.08)
Typ LN+LS	22	0.91	(1.19)	1.32	(1.04)	1.32	(0.89)

Note. *N* = 83 students in 24 small groups within 6 teachers, except for one Exp LN+LS student who was missing cross-modal cognitive processing measures at midtest and posttest.

Table 2. *Zero-order Correlations among Variables across Conditions*

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.
1. DLL Status	--																									
2. Pre Vocab	**-.72**	--																								
3. Pre Alphabet	**-.33**	**.32**	--																							
4. Pre Letter Naming Speed	**-.26**	**.27**	**.75**	--																						
5. Pre Taught Letter Names	**-.31**	**.24**	**.87**	**.83**	--																					
6. Pre Taught Letter Sounds	**-.23**	**.33**	**.48**	**.38**	**.38**	--																				
7. Pre Writing/spelling	-.19	**.29**	**.40**	**.49**	**.42**	**.27**	--																			
8. Pre CLP PAL	**-.28**	**.32**	**.34**	**.22**	**.29**	**.25**	**.24**	--																		
9. Pre CLP ARL	**-.41**	**.38**	**.23**	**.23**	.19	.20	.21	**.37**	--																	
10. Pre CLP OL	-.17	**.29**	.07	-.03	.01	**.22**	-.06	**.31**	.11	--																
11. Mid Letter Naming Speed	-.16	.17	**.51**	**.53**	**.58**	**.29**	**.31**	**.32**	**.33**	.06	--															
12. Mid Taught Letter Names	**-.26**	**.32**	**.59**	**.56**	**.61**	**.43**	**.34**	**.38**	**.26**	.19	**.86**	--														
13. Mid Taught Letter Sounds	**-.27**	**.35**	**.30**	.20	.19	**.56**	**.26**	.09	.18	.17	**.22**	**.43**	--													
14. Mid Writing/spelling	**-.31**	**.42**	**.28**	**.33**	**.32**	**.48**	**.53**	.21	.16	.10	**.40**	**.60**	**.44**	--												
15. Mid CLP PAL	-.13	**.24**	.01	.03	-.02	.14	.01	**.24**	**.35**	**.28**	.20	.19	**.24**	.08	--											
16. Mid CLP ARL	**-.35**	**.38**	**.34**	**.23**	**.24**	**.29**	.07	**.23**	**.56**	.21	**.42**	**.43**	**.30**	**.33**	**.39**	--										
17. Mid CLP OL	-.03	.17	.00	.01	-.04	.03	-.01	.12	.20	.16	-.08	-.09	-.15	-.08	-.06	.07	--									
18. Post Letter Naming Speed	**-.24**	**.30**	**.46**	**.38**	**.44**	**.38**	**.25**	**.31**	**.25**	.13	**.74**	**.80**	**.26**	**.52**	.10	**.37**	-.07	--								
19. Post Taught Letter Names	**-.25**	**.27**	**.56**	**.44**	**.48**	**.45**	**.31**	**.32**	**.26**	.13	**.73**	**.83**	**.36**	**.54**	.18	**.41**	-.15	**.88**	--							
20. Post Taught Letter Sounds	**-.39**	**.47**	**.39**	**.23**	**.26**	**.58**	**.33**	.13	.13	.19	**.24**	**.37**	**.58**	**.47**	.02	**.26**	.00	**.38**	**.41**	--						
21. Post Writing/spelling	**-.33**	**.48**	**.34**	**.39**	**.32**	**.40**	**.34**	.18	**.24**	.14	**.37**	**.52**	**.37**	**.64**	.14	**.41**	-.08	**.40**	**.48**	**.48**	--					
22. Post CLP PAL	-.19	**.28**	**.25**	.21	.16	**.29**	.14	**.41**	**.28**	**.23**	**.51**	**.51**	.15	**.23**	**.54**	**.38**	-.06	**.44**	**.51**	.18	**.32**	--				
23. Post CLP ARL	**-.24**	**.32**	.20	.08	.06	**.30**	-.02	**.22**	**.45**	.16	**.27**	**.35**	.18	**.32**	**.32**	**.71**	.05	**.38**	**.46**	**.23**	**.36**	**.47**	--			
24. Post CLP OL	.01	-.06	.11	-.07	-.02	-.03	-.02	.04	.05	.07	.02	.03	.06	-.03	-.01	.15	-.01	.12	.07	-.05	-.03	.06	**.25**	--		
25. Growth Rate CLP PAL	**-.23**	**.34**	**.22**	.18	.14	**.28**	.14	**.55**	**.39**	**.33**	**.46**	**.46**	.21	**.22**	**.79**	**.42**	-.01	**.37**	**.45**	.13	**.28**	**.91**	**.45**	.06	--	
26. Growth Rate CLP ARL	-.09	.17	.14	-.01	.00	**.24**	-.13	.05	.03	.17	.17	**.29**	.15	**.28**	.21	**.63**	-.04	**.30**	**.40**	.20	**.31**	**.39**	**.88**	**.27**	**.33**	--
27. Growth Rate CLP OL	.17	**-.32**	-.08	.00	-.01	-.21	.05	**-.33**	-.17	**-.93**	-.04	-.15	-.11	-.07	**-.23**	**-.23**	**-.49**	-.09	-.08	-.17	-.10	-.20	-.17	-.09	**-.30**	-.15

Note. N = 83 students in 24 small groups. Pearson's r reported (does not account for small group membership). Values in boldface are significant at the 0.05 level.

Table 3. *General Model Results for Alphabet Growth (Model 1)*

	Letter Naming Speed			*Taught Letter Names*			*Taught Letter Sounds*			*Writing/spelling*		
Fixed Effects	*Coeff*	*(SE)*	*p*	*Coeff*	*(SE)*	*p*	*Coeff*	*(SE)*	*p*	*Coeff*	*(SE)*	*p*
Intercept (Pretest)	**0.47**	**(0.18)**	**.025**	**0.69**	**(0.12)**	**<.001**	0.13	(0.13)	.343	0.13	(0.08)	.132
LN-Only	0.06	(0.29)	.846	0.21	(0.20)	.330	0.04	(0.22)	.874	0.18	(0.13)	.225
LS-Only	0.21	(0.30)	.513	0.14	(0.21)	.532	-0.14	(0.23)	.569	0.05	(0.14)	.732
Exp LN+LS	-0.30	(0.27)	.314	-0.28	(0.19)	.191	0.24	(0.21)	.297	0.07	(0.12)	.575
DLL Status	0.01	(0.24)	.962	-0.04	(0.17)	.794	0.07	(0.18)	.704	0.04	(0.11)	.753
Pretest Vocab (z)	-0.12	(0.24)	.632	-0.01	(0.17)	.952	0.14	(0.18)	.469	0.12	(0.11)	.286
Pretest Alphabet (z)	**0.92**	**(0.18)**	**<.001**	**1.14**	**(0.12)**	**<.001**	0.20	(0.14)	.161	**0.18**	**(0.08)**	**.044**
Change per Month	**1.18**	**(0.15)**	**<.001**	**0.97**	**(0.10)**	**<.001**	**0.85**	**(0.10)**	**<.001**	**0.41**	**(0.06)**	**<.001**
LN-Only	**1.14**	**(0.25)**	**.004**	**0.70**	**(0.16)**	**.005**	-0.31	(0.14)	.072	-0.02	(0.10)	.833
LS-Only	**-1.04**	**(0.26)**	**.007**	**-0.89**	**(0.17)**	**.002**	0.27	(0.15)	.121	-0.19	(0.10)	.103
Exp LN+LS	0.15	(0.24)	.561	**0.37**	**(0.15)**	**.048**	**0.33**	**(0.13)**	**.046**	0.11	(0.09)	.258
DLL Status	0.11	(0.21)	.599	0.05	(0.13)	.732	-0.12	(0.12)	.324	0.02	(0.08)	.837
Pretest Vocab (z)	**0.45**	**(0.21)**	**.044**	0.26	(0.13)	.065	0.18	(0.12)	.145	**0.23**	**(0.08)**	**.009**
Pretest Alphabet (z)	**0.42**	**(0.16)**	**.016**	**0.23**	**(0.10)**	**.030**	0.16	(0.09)	.082	0.04	(0.06)	.528
Random Effects		*Var*	*p*		*Var*	*p*		*Var*	*p*		*Var*	*p*
Between Students												
Pretest		0.00	>.500		0.03	>.500		0.04	>.500		0.02	>.500
Change/Month		**30.98**	**<.001**		**0.44**	**<.001**		**0.25**	**<.001**		**0.14**	**<.001**
Between Small Groups												
Pretest		0.00	>.500		0.00	>.500		0.00	>.500		0.00	>.500
Change/Month		0.00	>.500		0.00	>.500		0.00	.402		0.00	>.500
Between Teachers												
Pretest		0.02	>.500		0.00	>.500		0.00	>.500		0.00	>.500
Change/Month		0.01	>.500		0.01	>.500		0.02	.159		0.00	>.500
Residual (within Stud)		2.39			1.14			1.37			0.49	

Note. Three measurements for each student with $N = 83$ students in 24 small groups within 6 teachers, with pretest measurement time coded 0, midtest coded 1.87, and posttest coded 3.27 months; treatments effect coded +1, respectively, with Typ LN+LS coded –1 as reference group; observed *p*-values reported. Values in boldface are significant at the 0.05 level.

Table 4. *Fixed Effects Results for Pairwise Comparisons on Alphabet Growth (Model 2)*

Fixed Effect on	*Letter Naming*				*Taught Letter Names*				*Taught Letter Sounds*				*Writing/spelling*			
Change per Month	*Coeff*	*(SE)*	*p*	*d**	*Coeff*	*(SE)*	*p*	*d**	*Coeff*	*(SE)*	*p*	*d**	*Coeff*	*(SE)*	*p*	*d**
LN-Only v LS-Only	**1.04**	**(0.22)**	**<.001**	**1.50**	**0.74**	**(0.13)**	**<.001**	**1.87**	**-0.33**	**(0.11)**	**.003**	**-.97**	0.04	(0.06)	.542	.20
LN-Only v Exp LN+LS	0.61	(0.24)	.011	.78	0.21	(0.15)	.163	.43	-0.32	(0.12)	.011	-.78	-0.06	(0.08)	.483	-.21
LN-Only v Typ LN+LS	**0.79**	**(0.24)**	**.001**	**1.02**	**0.45**	**(0.14)**	**.002**	**.95**	0.02	(0.10)	.830	.07	-0.04	(0.09)	.598	-.16
LS-Only v Exp LN+LS	**-0.66**	**(0.16)**	**<.001**	**-1.29**	**-0.63**	**(0.12)**	**<.001**	**-1.62**	-0.06	(0.14)	.655	-.14	-0.15	(0.07)	.038	-.65
LS-Only v Typ LN+LS	0.13	(0.21)	.541	.19	0.13	(0.13)	.311	.32	0.03	(0.15)	.850	.06	0.18	(0.11)	.110	.51
Exp v Typ LN+LS	0.19	(0.18)	.296	.31	0.28	(0.13)	.024	.67	**0.33**	**(0.12)**	**.006**	**.83**	-0.01	(0.08)	.948	-.02

Note. Growth models estimated using 4-level models of three measurements for each student, $N = 83$ students in 24 small groups within 6 teachers, with pretest measurement time coded 0, midtest coded 1.87, and posttest coded 3.27 months; treatments effect coded with +1 for first condition listed and –1 for second condition listed; observed *p*-values reported with significant findings boldfaced after Dunn-Sidak *p*-value adjustment for six pairwise comparisons; *d** is effect size of difference between groups on growth, in approximate standard deviations taken from each condition's size and model-predicted coefficient standard error. Values in boldface are significant at the 0.0085 pairwise comparison adjusted level.

Table 5. *Using Cognitive Learning Process Growth to Predict Alphabet Growth (Model 3)*

	Letter Naming Speed			*Taught Letter Names*			*Taught Letter Sounds*			*Writing/spelling*		
Fixed Effects	*Coeff*	*(SE)*	*p*	*Coeff*	*(SE)*	*p*	*Coeff*	*(SE)*	*p*	*Coeff*	*(SE)*	*p*
Pretest	**0.45**	**(0.18)**	**.029**	**0.66**	**(0.12)**	**<.001**	0.14	(0.13)	.320	0.12	(0.08)	.162
DLL Status	0.02	(0.25)	.947	-0.03	(0.18)	.856	0.07	(0.19)	.721	0.05	(0.12)	.678
Pretest Vocab (z)	**0.89**	**(0.17)**	**<.001**	**1.10**	**(0.12)**	**<.001**	0.20	(0.13)	.156	0.14	(0.08)	.096
Pretest Alphabet (z)	-0.09	(0.24)	.711	0.01	(0.17)	.952	0.12	(0.19)	.520	0.14	(0.11)	.254
Change per Month	**1.16**	**(0.19)**	**<.001**	**0.96**	**(0.13)**	**<.001**	**0.85**	**(0.15)**	**<.001**	**0.42**	**(0.05)**	**<.001**
DLL Status	0.04	(0.23)	.854	-0.02	(0.14)	.873	-0.12	(0.12)	.362	0.03	(0.08)	.728
Pretest Vocab (z)	0.18	(0.24)	.479	0.04	(0.15)	.811	0.20	(0.13)	.160	**0.22**	**(0.08)**	**.019**
Pretest Alphabet (z)	**0.36**	**(0.16)**	**.045**	0.17	(0.10)	.106	0.10	(0.09)	.298	0.05	(0.06)	.387
PAL Growth (z)	**0.48**	**(0.16)**	**.008**	**0.38**	**(0.10)**	**.002**	-0.03	(0.09)	.745	0.03	(0.06)	.635
ARL Growth (z)	0.16	(0.14)	.266	**0.24**	**(0.09)**	**.016**	0.14	(0.08)	.082	**0.14**	**(0.05)**	**.021**
OL Growth (z)	0.13	(0.15)	.401	0.08	(0.09)	.418	-0.04	(0.08)	.591	0.05	(0.05)	.364
Random Effects		*Var*	*p*		*Var*	*p*		*Var*	*p*		*Var*	*p*
Between Students												
Pretest		0.01	>.500		0.05	>.500		0.05	>.500		0.02	>.500
Change/Month		**1.18**	**<.001**		**0.32**	**<.001**		**0.21**	**.002**		**0.13**	**<.001**
Between Small Groups												
Pretest		0.00	>.500		0.00	>.500		0.00	>.500		0.00	>.500
Change/Month		**0.34**	**.010**		**0.22**	**<.001**		0.10	.055		0.00	>.500
Between Teachers												
Pretest		0.01	.402		0.00	>.500		0.00	>.500		0.00	>.500
Change/Month		0.00	>.500		0.00	>.500		**0.06**	**.049**		0.00	>.500
Residual (within Stud)		2.43			1.16			1.39			0.50	

Note. Three measurements for each student with N = 82 students in 24 small groups within 6 teachers (1 Exp LN+LS student missing CLP mid/post), with pretest measurement time coded 0, midtest coded 1.87, and posttest coded 3.27 months; individual predicted CLP student growth rates (PAL, ARL, and OL) extracted from CLP growth models and standardized for use in the present alphabet outcomes growth model; observed p-values reported. Values in boldface are significant at the 0.05 level.

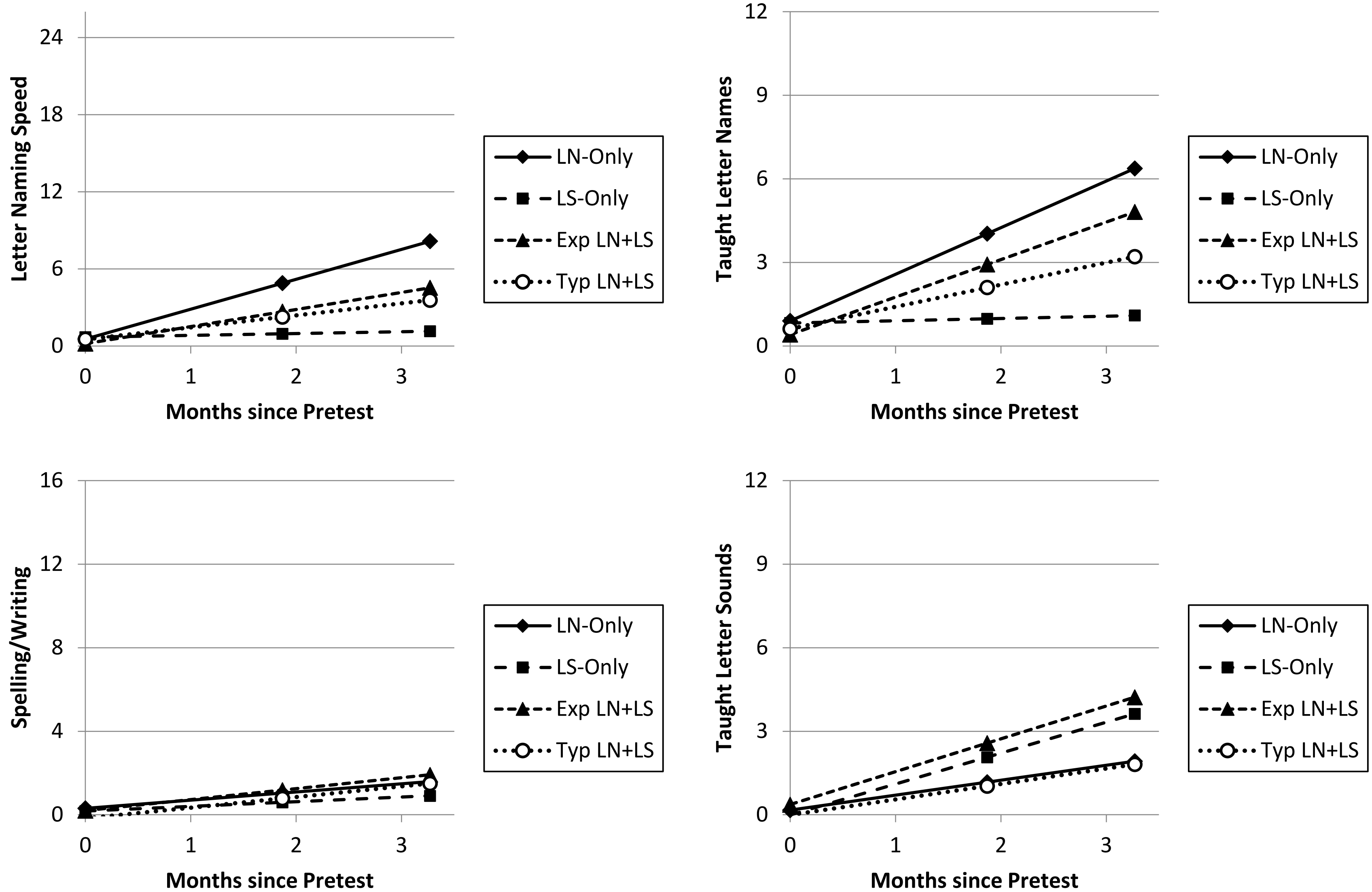

Figure 1. Model-Predicted Growth Trajectories of Alphabet Outcomes by Experimental Condition.

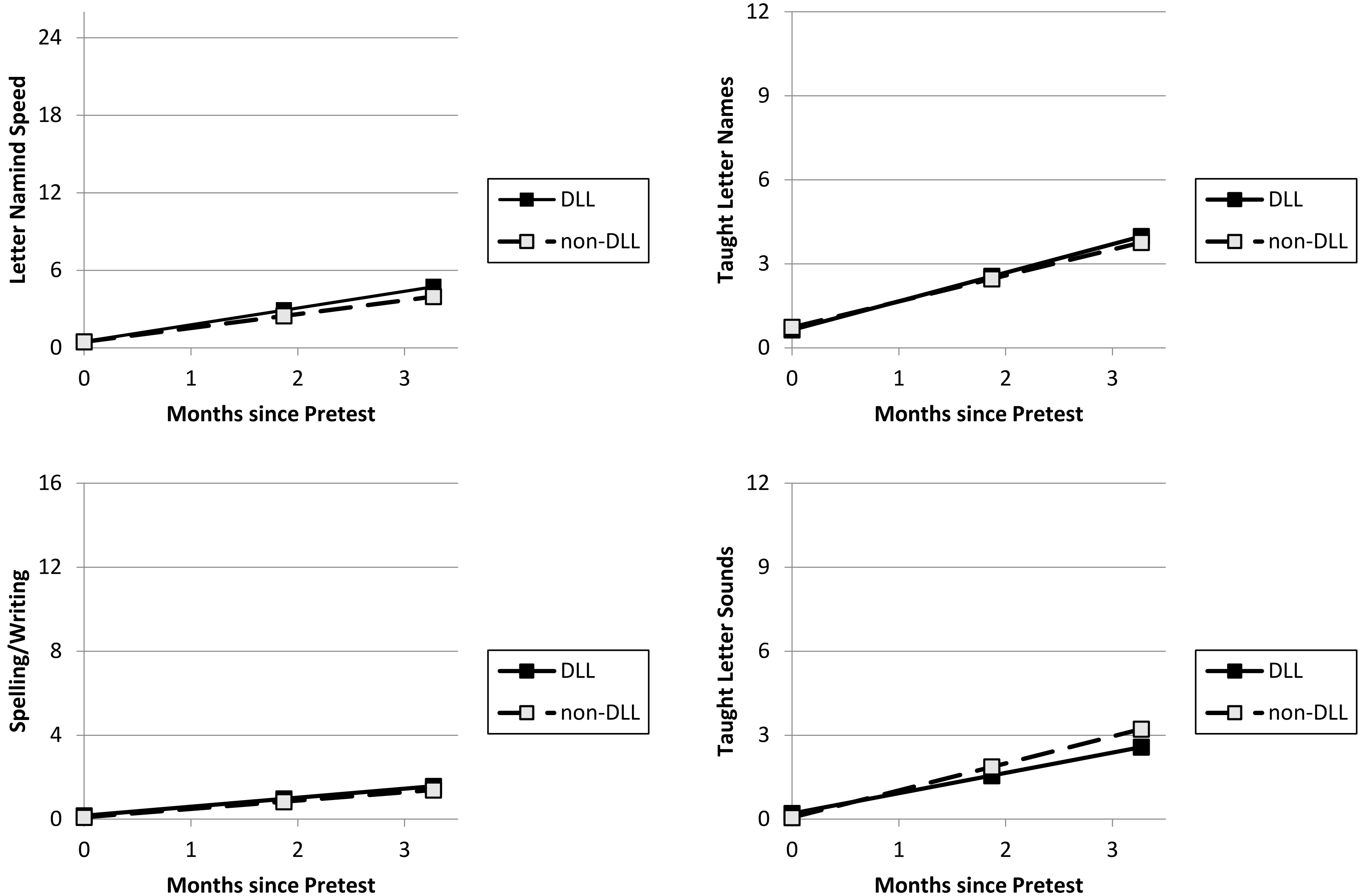

Figure 2. Model-Predicted Growth Trajectories of Alphabet Outcomes by DLL Status

Appendix

Table A1. *Previous Alphabet Learning Studies*

Study	*N*	*LN*	*LS*	*LN+ LS*	*LN+ PA*	*LS + PA*	*LN+ LS+ PA*	*Setting*	*Sample Characteristics*	*Effect Size: LN*	*Effect Size: LS*
Castles et al., 2009	76	X	X					Australian childcare centers	Low letter knowledge	0.34*	0.70*
Culatta et al., 2003	30			X				Head Start	NA	0.10 (ns)	
Farver, Lonigan, & Eppe, 2009	96						X	Head Start	English- & Spanish-speaking	0.42*	
Gettinger, 1986	72						X	Preschool	NA	1.27*	2.56*
Gillon, 2005	31						X	Clinic	Language-impaired	0.78 (ns)	
Murray, Stahl, & Ivey, 1996	42	X						State-funded preschool	86% AA	0.01 (ns)	
Nelson, Sanders, & Gonzalez, 2010	88						X	Head Start	English- & Spanish-speaking	1.22*	
Piasta, Purpura, & Wagner, 2010	58		X	X				Private preschool	72% white, 14% AA, 14% other	Production: 0.53* LN+LS>LS, LN+LS>C, LN=C (ns) Recognition: (ns)	Production: 0.47* LN+LS>C, LS=C (ns) Recognition: 0.29* LN+LS>C, LS=C (ns), LS=LN+LS (ns)
Roberts, 2003	33				X			State-funded preschool	English-, Hmong-, & Spanish-speaking	1.00*	
Whitehurst et al., 1994	167						X	Head Start	46% white, 45% AA, 1% Asian	0.39*	
Woodrome & Johnson, 2009	28	X						Public & private	Low letter knowledge (75% at-risk)	0.00 (ns)	
Yeh, 2003	44					X		Head Start	11% white, 41% AA, 41% Hispanic, 7% Asian		0.79*