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Three treatments for bilingual children with primary language impairment: Examining cross-linguistic and cross-domain effects

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Abstract

Purpose—This study examines the absolute and relative effects of three different treatment programs for school-aged bilingual children with primary or specific language impairment (PLI). It serves to expand the evidence base on which service providers can base treatment decisions. It also explores hypothesized relations between languages and cognition in bilinguals with PLI.

Method—Fifty-nine school-aged Spanish-English bilingual children with PLI were assigned to receive nonlinguistic cognitive processing, English, bilingual (Spanish-English), or deferred treatment. Participants in each of the three active treatments received treatment administered by nationally certified speech-language pathologists. Pre- and post-treatment assessments measured change in nonlinguistic cognitive processing, English, and Spanish skills, and analyses examined change within and across both treatment groups and skill domains.

Results—All active treatment groups made significant pre- to post-treatment improvement on multiple outcome measures. There were fewer significant changes in Spanish than in English across groups. Between group comparisons indicate that the active treatment groups generally outperformed the deferred treatment control, reaching statistical significance for two tasks.

Conclusions—Results provide insight into cross-language transfer in bilingual children and advance understanding of the general PLI profile with respect to relationships between basic cognitive processing and higher level language skills.

Primary or specific language impairment (PLI)[1] is a high-incidence developmental disorder characterized by poor language abilities not attributable to frank neurological, sensory, cognitive or motor impairments or to environmental factors (Leonard, 1998; Schwartz, 2009). PLI is chronic, although the most observable symptoms may shift with severity of impairment, characteristics of the ambient language(s) to be learned, and the individual's developmental stage. Bilingual children with PLI demonstrate impairment in both of their

[1]The terms Specific Language Impairment (SLI) and Language Impairment (LI) are commonly used to refer to this disorder. The term Primary Language Impairment and acronym PLI are used here to acknowledge the subtle nonlinguistic weaknesses apparent in the disorder and to avoid visual confusion between the acronyms LI and L1.

languages, as compared to chronological age peers with similar language-learning experiences. For children with PLI, timely, effective intervention is viewed as essential for improving language and, by extension, academic and social outcomes. To date, there is a fundamental lack of empirical evidence to inform treatment protocols for bilingual school-age children with PLI.

In this study we investigate the absolute and relative effectiveness of three different treatment programs on language and cognitive outcomes in Spanish-English bilingual school-age children with PLI. Two of the treatment programs focus directly on language and are administered in English-only or in a combination of Spanish and English. The third program focuses on basic cognitive processing mechanisms. All three treatment programs are administered by a speech-language pathologist (SLP) and employ a combination of computer-based and interactive training strategies. The benefit of each of the three treatments is determined using multiple measures in Spanish and English as well as select cognitive processing tasks; this combination of outcome measures allows us to investigate the potential for generalization from treated to untreated skills within each language, across languages, and across cognitive-linguistic domains.

It may be that acquisition and generalization are possible under a wide range of training conditions or that certain conditions are more effective in promoting gains in Spanish and English in bilingual children with PLI. In addition to the clear practical need for treatment studies at the intersection of PLI and bilingualism, such investigations also provide a unique vantage point from which to consider key theoretical issues regarding the nature of cross-language and cross-domain relationships. We first present a brief review of the language and cognitive characteristics of bilingual children with PLI that motivate the current study, focusing on U.S. children who learn Spanish as a home or first language (L1) and English as their second language (L2).

Language in Bilingual Children with PLI

PLI is presumed to be due to innate factors, either specific to language or in more general cognitive mechanisms, interacting with language-learning demands. Despite recent advances in the genetics and neurobiology of PLI (e.g., Newbury, Fisher, & Monaco, 2010), the precise cause of the disorder is not known and PLI is still diagnosed on the basis of behavioral evidence. Diagnosis in bilingual learners is complicated by the diversity of language experiences within this population. The underlying impairment is known to affect both languages in bilingual children, but the determination of what constitutes impairment in each language must be done in reference to peers with similar experiences.

Despite the complexity of identifying PLI in bilingual groups, a growing literature characterizing Spanish-English bilingual school-age children with PLI has arisen. These children have a history of delayed language acquisition (Restrepo, 1998) and perform significantly below their unaffected bilingual peers in various language areas, including lexical-semantics (Sheng, Peña, Bedore, & Fiestas, 2012), morphosyntax (Gutierrez-Clellen, Restrepo, & Simon-Cereijido, 2006), and code-switching in discourse production (Iluz-Cohen & Walters, 2012). Spanish-English bilingual children with PLI also perform more poorly than typically developing bilingual children on language processing tasks, including nonword repetition (Windsor, Kohnert, Lobitz, & Pham, 2010), rapid automatic naming (Kohnert & Windsor, 2012), and novel morpheme learning (Jacobson & Schwartz, 2005). Furthermore, Spanish-English bilingual school-age children with PLI score significantly lower than their typical bilingual age peers in L1 and L2 on some standardized tests of language, including Spanish and English versions of the Clinical Evaluation of Language Fundamentals (Semel, Wiig, & Secord, 2003; Wiig, Secord, & Semel, 2006) (see Windsor et al., 2010). These weaknesses in oral language contribute to challenges with written language, putting bilingual children with PLI at significant academic and social risk.

In bilingual learners with PLI, however, the relative levels of proficiency in the L1 and L2 may change with age and experience as well as with the particular aspect of language measured. That is, the bilingual learner with PLI may be relatively stronger in Spanish on many tasks at age 6 but have greater skill in, as well as a preference for, English on these same measures by age 8. This within-child shift from relative strength in L1 to L2 is not unique to bilingual learners with PLI. The common finding for typically developing school-age bilingual learners in the US is that skills in the minority L1 plateau, regress or increase slowly alongside the rapid upward trajectory of English, a growth pattern which ultimately results in greater proficiency in L2 (e.g., Kohnert, 2002; Pham & Kohnert, 2012; Sheng, Lu, & Kan, 2011). For children with PLI, inherent difficulty with language learning may lead to much slower growth in L2 (English) and a potential decline in the L1 or home language (Spanish) (Restrepo & Kruth, 2000), although longitudinal research on bilingual children with PLI is needed to establish this growth pattern. This within-child variation in relative strength of Spanish and English over time presents significant challenges to quantifying outcomes of longitudinal treatment programs.

Treatment of bilingual children with PLI

When bilingualism is inherent in a child’s life circumstances, clinical actions which support gains in both languages are considered optimal for improving long-term academic and social outcomes in children with PLI (Kohnert, 2013; 2010; Restrepo, Morgan, & Thompson, 2012). The reality is, however, that minority L1 learners with disabilities receive even fewer L1 support services and are more likely to be instructed only in English as compared to their unaffected minority L1 peers (Zehler et al., 2003). There are at least three reasons for the prevalent use of “English-only” treatment with bilingual children with PLI. First, there is a critical shortage of bilingual SLPs, resulting in a frequent mismatch between child and provider languages (e.g., Kohnert, Kennedy, Glaze, Kan, & Carney, 2003; ASHA, 2010). Second, English is the primary language of academic and vocational success, leading some to believe that it should also be the sole focus of instruction. Third, because school-age children may have greater skills in English than in their L1, building on the current strength may have some face validity in addition to immediate educational relevance. Ultimately, however, the practice of English-only treatment has not been thoroughly vetted, and SLPs have little evidence on which to base this or alternative clinical recommendations.

We found only two previous group studies that investigated treatment effectiveness in bilingual children with PLI (Perozzi & Sanchez, 1992; Restrepo et al., 2012). Both studies focused on vocabulary training in participants who spoke Spanish (L1) and English (L2). In each, the same set of vocabulary used in training was used to evaluate training effectiveness and the interventionists were graduate students or teachers rather than SLPs. Perozzi and Sanchez (1992) divided 38 bilingual first graders with low oral language scores into two treatment groups. One group received vocabulary training in Spanish (L1) until criterion was reached and then English (L2) training was initiated. The other treatment group received vocabulary training only in English. The bilingual treatment group obtained criterion-level performance on target vocabulary items in both Spanish and English faster than the English-only group learned English vocabulary. Restrepo and colleagues (2012) divided 202 preschool children (aged 4;0–5;4) into four different treatment conditions: English vocabulary, Spanish-English vocabulary, English math, or bilingual math training. On English vocabulary measures, the two groups that received vocabulary training (i.e., English-only and bilingual) performed comparably to each other and better than the math groups. On Spanish vocabulary measures, the bilingual vocabulary group outperformed all others. In general, both studies support the efficacy of bilingual treatment programs, at least for vocabulary, in somewhat younger children than those included in the current study. The effects of language treatment programs on other language domains, and on untrained exemplars, remain unexplored.

In summary, there is very little empirical basis for determining whether school-age children with PLI can transfer learned skills from a treated to an untreated language, as well as whether the direction of transfer is unidirectional or bidirectional (i.e., from L1 to L2 or L2 to L1 or both). Further investigation in this area is needed.

Cognitive Processing Skills in PLI

Although the essential marker of PLI is poor language as compared to age peers, subclinical weaknesses in basic cognitive processing mechanisms are part of the PLI profile. In the monolingual PLI literature, there is substantial evidence of cognitive processing weaknesses. These weaknesses can be categorized into three major areas: speed of information processing, sustained selective attention, and working memory. First, children with PLI are slower than typically developing peers to complete a variety of tasks that involve little or no language, including shape rotation, auditory and visual signal detection or judgments, and arithmetic (e.g., Kohnert & Windsor, 2004; Leonard et al., 2007; Miller et al., 2006); these findings have been interpreted as evidence of subtle impairment in information processing speed within the PLI population. Secondly, at the group level children with PLI perform more poorly on sustained and selective attention tasks that use nonlinguistic as well as linguistic stimuli. In a meta-analysis (Ebert & Kohnert, 2011), children with PLI were found to perform below typically developing peers on Continuous Performance Tasks (CPTs, also known as go/no-go, monitoring, or vigilance tasks) the prototypical assessment of sustained and selective attention (Mirsky et al., 1991). Finally, the presence of working memory weaknesses in children with PLI is well-supported. Although substantial focus has been placed on verbal working memory deficits (e.g., Montgomery, Magimairaj, & Finney, 2010), evidence indicates that working memory deficits in PLI extend to nonlinguistic information processing as well (e.g., Hoffman & Gillam, 2004; Leonard et al., 2007).

The majority of work on cognitive processing in children with PLI has been conducted with monolingual children. However, at least one recent study demonstrates nonlinguistic cognitive processing weakness in bilingual children with PLI as well. Kohnert and Windsor (2012) found that bilingual school-age children with PLI were slower than unaffected bilingual and monolingual age peers in responding to the presence of a red or blue circle and less accurate in recalling the sequence of tones.

The nature of the relationship between these well-documented, albeit subtle, cognitive processing weaknesses and the more obvious language deficits in PLI is not yet clear. One argument, consistent with language specific or modular theories of PLI, is that the nonlinguistic cognitive processing weaknesses co-occur with the defining language deficit, but are not causally related to it (Paradis, 2010). An alternative perspective, consistent with more general cognitive theories of language and the Limited Processing Capacity view of PLI (Leonard et al., 2007) is that the subtle weaknesses in attention, processing speed and working memory form a core part of PLI and directly contribute to the more obvious language impairment (Kohnert & Ebert, 2010). Evidence of cross-domain generalization – that is, transfer of gains from the nonlinguistic cognitive domain to the language domain – would be most consistent with domain-general theories of language and PLI.

Two single-subject experimental design intervention studies provide preliminary support for the idea that treating underlying nonlinguistic cognitive processing skills could have a positive effect on language skills in children with PLI. Ebert and Kohnert (2009) treated nonlinguistic processing speed and memory in two monolingual English-speaking children with PLI. Results of the brief intervention program suggested that the participants made gains in processing speed and in some language skills, including sentence formulation and grammatical morpheme production. The results were replicated and extended to bilingual children in Ebert, Rentmeester-Disher, and Kohnert (2012). The nonlinguistic treatment program in the second study targeted processing speed and attention; both participants made gains in Spanish and in English, suggesting that the nonlinguistic cognitive treatment mechanism improved language skills.

While both studies were preliminary investigations with few participants, they clearly provide an indication of the feasibility of cross-domain generalization from the nonlinguistic cognitive domain to language in children with PLI. Cross-domain generalization in the opposite direction is also conceivable. That is, treating language skills could result in improved cognitive processing skills. There is some support for the idea that intensive language interventions improve attention skills. Stevens, Fanning, Coch, Sanders, and Neville (2008) reported that deviant event-related potential patterns, indicative of deficits in selective attention, were reduced following intensive computerized language intervention in children with PLI. In addition, Gillam et al. (2008) speculated that the intensive language interventions provided in their study to English-speaking children with PLI may have improved underlying attention skills, leading to comparable gains across four different treatment groups. However, attention skills were not measured directly in that study. Direct investigation of the potential for, or limits on generalization between language and cognitive processing in PLI is warranted.

Study Purpose and Design

This study examines the effects of three distinct treatment programs on language and cognitive processing outcomes in Spanish-English bilingual school-age children diagnosed with PLI. Participants are assigned to one of the following programs, administered by SLPs: (1) nonlinguistic cognitive processing treatment, which trains attention and processing speed using nonlinguistic stimuli; (2) English language treatment, which trains English vocabulary and morphosyntactic skills; or (3) bilingual treatment, which trains predominantly Spanish vocabulary and morphosyntactic skills but uses English to make explicit cross-linguistic connections. Participants in a fourth, deferred treatment condition continued to receive their regular prescribed special education services from their school-based SLP, but did not receive one of the experimental intensive treatments during the study period and served as a control group.

We are interested in absolute change resulting from each of the three active treatment programs as well as a comparison between the three treatments and control to determine relative effectiveness. Treatment effectiveness is operationalized in two ways, within the context of generalization; both forms of effectiveness entail generalization beyond treated stimuli, to untrained pre- and post-testing measures. First, improvement on measures in the *treated* language or domain is considered evidence of treatment effectiveness (i.e., English treatment resulting in improved performance on untrained tasks in English, nonlinguistic cognitive treatment resulting in improved performance on cognitive processing tasks that differed from those used in training, or bilingual treatment resulting in improved performance on untrained tasks in Spanish and English). The second type of evidence indicating treatment effectiveness is improved performance in an *untreated* language or domain (e.g., better skills in Spanish following English-only treatment or faster performance on cognitive processing measures following bilingual treatment). For all participants, pre- and post-treatment skill levels are measured in Spanish and in English using standardized tests and experimental measures; experimental tasks indexing sustained selective attention, processing speed, and working memory are used to assess nonlinguistic cognitive processing before and after treatment.

From a practical perspective, if all three training programs result in significant and comparable gains in language outcomes, then evidence-based options for clinicians are increased substantially. If bilingual training proves substantially more effective in increasing outcomes in Spanish and English, then specific treatment tools and guidelines can be developed which allow children access to enriched training activities in both languages, perhaps using a combination of computer-based and interactive approaches to compensate for the shortage of bilingual providers. On the other hand, if the cognitive training produces language results comparable to or better than the bilingual training, it may be possible for training implemented by a monolingual SLP to generalize or support the development of both the L1 and L2. In this case, cognitive training could help reduce the significant mismatch in client-clinician languages, perhaps moving beyond Spanish-English to the hundreds of other home languages spoken by children in the US (U.S. Bureau of Census, 2000). It is also possible that the cognitive skills that have been found to be weak in children with PLI are not modifiable with training or, if modified, have no effect on functioning in either L1 or L2. This finding would be important for guiding clinical recommendations as well as shaping theory.

Method

Participants

Data from 59 Spanish-English bilingual children with PLI are reported here. Participants were 50 boys and 9 girls ranging in age from 5;6 to 11;2 at the time of study enrollment. All participants attended one of eight different schools in the Minneapolis Public School district and were receiving special education services for language disorder. To qualify for these special education language services, each participant had (1) scored substantially below expectations for bilingual chronological age peers in both languages on at least two nonstandardized or standardized assessments and (2) did not have another diagnosis (e.g., cognitive or global developmental delay, autism spectrum disorder, or other health impairments) to explain the language impairment (Minnesota Office of the Revisor of Statutes, 2008).

A number of additional steps were taken during recruitment and pre-testing sessions to verify the PLI status of participants. First, all participants passed a hearing screening at 20dbHL at 1000, 2000 and 4000 Hz. All participants also completed the *Test of Nonverbal Intelligence – 3rd Edition* (TONI-3, Brown et al., 1997), with a score no more than 1.25 standard deviations below the mean. Finally, parent interviews were used to confirm parental concern with language development (cf. Restrepo, 1998) as well as the absence of hearing problems, autism, head injury, cerebral palsy, seizures, general cognitive delay, or physical problems. Pre-treatment language testing also confirmed notable language delays in both languages; as a group, participants could be characterized as demonstrating moderate-severe language impairment (see Table 1 for pre-treatment testing scores).

All participants had systematic exposure to both Spanish and English. The parents of all participants reported that they spoke Spanish “most” or “all” of the time at home. In addition, the predominant language of instruction at all school sites was English. Four of 59 participants were reported to receive some classroom support in Spanish during their participation in the study, through limited Spanish programming (e.g., two hours per day of literacy instruction) or through bilingual teachers.

Pre- and Post-Treatment Measures and Procedures

Pre- and post-treatment testing was conducted to measure skills in three areas: Spanish, English, and nonlinguistic cognitive processing. Pre- and post-treatment testing was conducted by a team of undergraduate and graduate students in speech-language-hearing sciences. A certified speech-language pathologist was on-site to supervise students during testing sessions. All examiners were trained on the assessment tasks before administering them to participants. All examiners who administered tasks in Spanish were fluent Spanish speakers. When possible, Spanish and English assessments were conducted on separate days, with the initial language of testing counterbalanced across participants; when separation across days was not possible, languages were separated by examiner. In all cases, post-treatment testing was conducted by individuals not involved in treatment.

Language measures—Three standardized language tests were administered in both English and Spanish: the Expressive One-Word Picture Vocabulary Test (EOW-E, Brownell, 2000a) and the Expressive One-Word Picture Vocabulary Test - Bilingual Edition (EOW-S, Brownell, 2001a) provided measures of expressive vocabulary; the Receptive One-Word Picture Vocabulary Test (ROW-E, Brownell, 2000b) and the Receptive One-Word Picture Vocabulary Test – Bilingual Edition (ROW-S, Brownell, 2001b) provided measures of receptive vocabulary; and the Core Language score from the Clinical Evaluation of Language Fundamentals – 4th Edition in English (CELF-4E, Semel et al., 2003) and in Spanish (CELF-4S, Wiig et al., 2006) provided measures of global language skills. Only the 4 subtests composing the Core Language score for each of the relevant age ranges (5–8 and 9–11) were administered.

A short time into the data collection process, a decision was made to deviate from the publisher's recommended "bilingual administration" procedures for the EOW-S and ROW-S (in which either Spanish or English responses are accepted) and move to Spanish-only administration and scoring. This single language administration was needed to fully understand the impact of treatment on each language, and provided an exact parallel to the administration and scoring procedures for the English versions of these vocabulary tests. The switch in administration methods for the two Spanish vocabulary tests was made after data from some participants had already been collected bilingually, following the test manuals. Data from different administration and scoring methods could not be reliably combined. As such, only scores obtained entirely in Spanish for the EOW-S and ROW-S are reported here, and participant numbers are lower in some groups for these two measures (see Table 1 for these numbers).

In addition to the standardized language measures, children completed nonword repetition (NWR) tasks in both Spanish (Ebert, Kalanek, Cordero, & Kohnert, 2008) and English (Dollaghan & Campbell, 1998). The NWR tasks served as a processing-dependent measure of language skill, in complement to the more experience-dependent vocabulary and global language measures. Responses on the NWR tasks were digitally recorded and later scored by trained research assistants. Scoring procedures followed Dollaghan and Campbell (1998); deleted and substituted phonemes were counted as incorrect, whereas added phonemes and distorted phonemes were not. The number of correct phonemes was divided by the total number of phonemes to create a percent phonemes correct (PPC) score. PPC scores from only the longest words in each language (5-syllable words in Spanish and 4-syllable words in English) were used as the dependent variable because longer words appear most sensitive to PLI (Dollaghan & Campbell; Windsor et al., 2010).

In order to calculate interjudge reliability for NWR scoring, 20% of audio files in both Spanish and English were randomly selected for re-scoring by a second transcriber. Results were compared on a phoneme-by-phoneme basis to the original scores, with a resulting overall interjudge reliability score of 87.5%.

Nonlinguistic cognitive measures—Three tasks were used to index nonlinguistic cognitive processing skills before and after treatment; each task was designed to capture skills in one of the three major areas of nonlinguistic cognitive processing weakness in PLI (processing speed, sustained selective attention, working memory). All tasks were implemented using the E-Prime software package (Psychology Software Tools, Inc., 2000). The first task, Choice Visual Detection (CVD), provides a measure of processing speed in the visual domain. Participants were asked to react as quickly as possible to the appearance of a red or blue circle on a computer screen. A block of 25 trials was administered and resulting reaction times were trimmed to remove outliers greater than 2000 milliseconds, less than 50 milliseconds, or outside two standard deviations of the individual's mean. Mean reaction time following trimming served as the dependent measure from the task. Complete task specifications appear in Kohnert and Windsor (2004).

The second task, Sustained Selective Attention (SSA), is a CPT in which participants are asked to monitor a stream of auditory environmental noises (traffic related sounds) for a target sound (keys rattling). The task was derived from those described in Spaulding, Plante, and Vance (2008) and Finneran, Francis, and Leonard (2009), which were both used to successfully separate children with PLI from typically developing peers. Complete specifications for the current task are found in Ebert (2011). Participants listened to 80 instances of each of five sounds, in random order. Sounds were 500 milliseconds in duration and total task duration was approximately 10 minutes. The dependent variable for the Sustained Selective Attention task was *d'* (d-prime; Macmillan & Creelman, 1991), which combines the participant's hit rate for target sounds with his or her false alarm rate for distracter sounds. The resulting value is an overall index of signal detection ability in standard deviation units.

The third nonlinguistic cognitive processing task, Auditory Serial Memory (ASM), assesses short-term memory for nonverbal auditory information (tones). Participants are asked to determine whether a pair of tone sequences are the same or different (see Yim, 2006, for complete task specifications, and Kohnert & Windsor, 2012, for task specificity and sensitivity to PLI in bilinguals). Sequences begin at two tones and progress in length to five tones each, with 15 trials at each sequence length. Participants were assigned a task score according to the longest sequence length at which they could accurately distinguish between the same and different pairs of tone sequences, with the criterion for accuracy set at 11 of 15 trials correct. This standard was derived from several clinical speech-language pathology sources that suggest a skill is "acquired" at 75% accuracy (e.g., Bleile, 1995; Boudreau & Hedberg, 1999). Thus, participants who were unable to complete task training or unable to reach 11 correct responses at the easiest level of difficulty (two-tone sequences) were assigned a score of 0. Participants who reached at least 11 correct responses for two-tone sequences received a task score of 1. Participants who scored at least 11 of 15 for both two- and three-tone sequences received a score of 2. This scoring system was continued for the remaining two levels of the task; thus, those participants who demonstrated accuracy at all task levels received a score of 4.

Treatment Programs

There were three active treatment conditions: nonlinguistic cognitive processing, English, or bilingual (Spanish-English) treatment. Participants in a fourth study condition, the deferred treatment control group, did not receive one of the experimental treatments during the period between pre- and post-testing. However, participants in all four conditions continued to receive language treatment services from their school-based SLP, consistent with their individualized education plans, as it was considered unethical to remove these educational services as a condition for participating in the study. These school-based language treatment services were delivered for approximately 30 to 60 minutes each week for each child, in English, across all groups. Thus, comparisons between active treatment groups and the deferred treatment control group index the effects of the experimental treatment programs beyond the typical support provided in schools. The experimental treatment programs were implemented on an intense basis (360 minutes per week) in order to maximize differences between school-based services alone and school-based services plus experimental treatment.

The three active treatment programs differed only in the content of activities, with all other aspects of treatment held constant across programs. Thus, all treatment sessions contained 75 minutes of therapeutic activities, divided across four or five activity periods of equal length, and evenly distributed between computer-based and interactive activities. In each case, the active treatment was administered by a Master's level SLP with experience in working with linguistically diverse children (see **Interventionists** below).

School district policy did not allow children to be removed from regular educational programs for study participation. Therefore, all treatment sessions were conducted at participants' school sites in place of after school or summer school programming. Sessions were scheduled at a rate of four sessions per week for approximately six weeks. Due to variations in the schedule for after-school and summer school programming, the number of treatment sessions offered to participants varied from 17 to 24 (depending on the time of year they participated). In addition, due to imperfect attendance at treatment sessions, the number of sessions completed ranged from 13 to 24 across individual participants. However, the number of treatment sessions completed did not vary significantly across the three treatment groups ($F = 2.21$, $p = 0.121$). Pre- and post-testing procedures required an additional four to eight sessions. Thus, for children in each of the active treatment groups, the total number of study sessions needed to complete all pre-testing, treatment, and post-testing procedures was approximately 30 over the course of eight weeks.

Nonlinguistic cognitive processing treatment—The nonlinguistic cognitive processing treatment was identical to the program described in Ebert et al. (2012). Participants completed activities designed to improve processing speed and attention skills, using nonlinguistic stimuli (e.g., shapes, colors, tones, or noises). Working memory (the third area of nonlinguistic cognitive processing weakness that was assessed in this study) was not treated directly (see Ebert et al., 2012, for discussion). The program contained three computer games from the Locutour Multimedia Attention and Memory: Volume II software package (Scarry-Larkin & Price, 2007). The games required children to scan a visual array for target symbols (*Scan*), to rotate and align domino tiles according to matching symbols or arithmetic problems (*Dominoes*), and to monitor visual stimuli for a target which frequently changes (*Change*). In the three interactive games, participants played a card game requiring rapid sorting and matching of visual symbols (*Blink*, Staupe, 2002); followed command sequences indicated only by musical noises (*Bop-It*); and replicated tone and light sequences of increasing length (*Simon Trickster*). These activities required participants to respond quickly, targeting processing speed, and to focus on a limited number of relatively uninteresting stimuli, targeting sustained selective attention.

Although all activities used nonlinguistic stimuli, monolingual English-speaking clinicians administering the nonlinguistic cognitive processing treatment were encouraged to interact normally with participants; that is, they spoke naturally in English to redirect and reinforce participants as they completed treatment activities. At the same time, clinicians were specifically instructed to avoid using any forms of linguistic cuing (e.g., conversational recasting, expansions, or corrections), and compliance was verified by treatment fidelity review.

English treatment—The English treatment program was designed to be a more traditional evidence-based language treatment program, in which the targets of intervention are vocabulary, morphosyntactic constructions, and auditory comprehension in the form of following directions. Activities were chosen based on the limited treatment literature for English-speaking school-aged children with language disorders, which provides some support for the use of computer-based programs (Gillam et al., 2008) and for semantically-based vocabulary treatment (Cirrin & Gillam, 2008). We applied the additional constraint that the English treatment program mirror the nonlinguistic cognitive processing treatment program (i.e., contain a mixture of computer-based and interactive activities), and also added games to target morphosyntactic constructions, a characteristic area of weakness in bilingual children with PLI (Gutierrez-Clellen et al., 2006). Participants in the English language treatment program completed two computer games published by Laureate Learning Systems, *Swim, Swam, Swum* and *Adjectives & Opposites*, and one published by Earobics, *Calling All Engines*. These computer games asked children to select correct irregular verb forms, to identify items based on descriptive vocabulary, and to follow directions of increasing length. All three interactive games in this treatment condition are produced by LinguiSystems, Inc; children were asked to name categories (*Category Card Games*), produce various morphosyntactic constructions (*Gram's Cracker*), and identify items based on verbal description (*Plunk's Pond*).

Clinicians interacted verbally with the children in English to redirect them to activities and reinforce performance. There was no Spanish stimulation provided by the activities or SLPs in this English-only treatment.

Spanish-English bilingual treatment—In the bilingual treatment program, SLPs were instructed to provide treatment primarily in Spanish (i.e., they were given an explicit goal of using Spanish at least 80% of the time) and to incorporate English to make explicit cross-linguistic connections, clarify instructions, or reinforce positive behavior. Participants were allowed to use Spanish or English with the SLP and other children. When children addressed the SLP in English, the SLP responded in English and recasted in Spanish. The bilingual treatment program utilized interactive activities in Spanish and computer activities in both English and Spanish.

The bilingual treatment program used the same three interactive activities as the English treatment program (*Category Cards, Plunk's Pond, Gram's Cracker*), translated into Spanish and modified to focus on Spanish vocabulary and morphosyntax. All translations were completed by a native Spanish speaker and reviewed by two bilingual SLPs for accuracy and agreement. Written Spanish labels were added to the sets of cards in Category Cards to promote categorization skills in Spanish and connections between English and Spanish labels. Vocabulary items and "clues" (i.e., definitions and attributes) in Plunk's Pond were translated into Spanish. Forty-two translated items with high phonological similarity were selected using a scoring system for phonological overlap between English and Spanish (see Kohnert, Windsor, & Miller, 2004). An additional 58 items were generated using a list of Spanish-English cognates commonly found in children's books (Colorín Colorado, 2010). The resulting total of 100 items was comparable to the number of items in Plunk's Pond as used in the English treatment program. Finally, 100 items were created for Gram's Cracker to target Spanish morphosyntax features cited in the empirical literature of Spanish-speaking children with PLI (Restrepo & Gutiérrez-Clellen, 2012). Targets included singular and plural clitics (e.g., "LO besa"), definite articles (e.g., "LAS casas"), indefinite articles (e.g., "UNOS carros"), regular and irregular preterite verb tense (e.g., "El niño ya COMIÓ"), reflexive verbs (e.g., "Él SE baña"), subjunctive (e.g., "La mamá quiere que COMA"), noun-verb agreement "e.g., "Los niñOS corrEN"), and adjective agreement ("la niñA altA").

Consistent with the English treatment program, children completed three computer-based activities in addition to the three interactive activities. Participants completed one activity solely in English, *Calling all Engines* by Earobics, the same activity as in the English treatment program, and one computer activity solely in Spanish, *Rosetta Stone Spanish (Latin American):* Level 1, Units 1 to 7, which focused on comprehension of sentence-level information and Spanish grammatical structures. Participants listened to phrase and sentence-level information and identified corresponding pictures in a field of four. For the third computer activity, children alternated between two bilingual software programs that could be completed in either Spanish or English modes: *Early Classifying Games* by MagneTalk and *My House, My Town, My School Bilingual Package* by Laureate Learning Systems. Both games focus on building vocabulary.

Deferred treatment control—Children in the deferred treatment control group had no contact with study personnel in between the pre- and post-testing sessions. For logistical and ethical reasons, the deferred treatment control group was composed of children who were scheduled to receive active treatment during a subsequent study cycle. That is, after completing post-testing for the deferred treatment control group, participants went on to complete one of the three active treatment protocols.

Interventionists

Five nationally certified SLPs administered the treatments. Each SLP had an earned Master's degree in speech-language-hearing sciences and disorders and had experience working with children from diverse backgrounds. Two of the SLPs were fluent Spanish speakers, with experience delivering speech-language treatment in Spanish. Only these two individuals delivered the bilingual treatment. The remaining three SLPs did not speak Spanish, and administered the nonlinguistic cognitive processing treatment, English treatment, or both (albeit during different sessions). For all three treatments, training manuals were created to ensure consistent administration of the treatment protocol; all SLPs were trained using these manuals before working with participants and had access to them throughout treatment.

Procedures

Group assignments—Recruitment was conducted via school district personnel, who identified eligible participants and informed them of the study. Interested families were screened over the phone. For participants not already enrolled in afterschool or summer school programming, research staff collaborated with school staff to help families enroll in after-school or summer school programming. Initial pre-testing sessions then took place at the school sites.

Following recruitment and pre-testing, children were assigned to a treatment condition (i.e., nonlinguistic cognitive processing, English, bilingual, or deferred treatment control). Children were first grouped according to their school site, because treatments were conducted at the school sites. Each group contained two to three children; at schools with enough participants to form multiple groups, children were assigned randomly to a group. Each group was then randomly assigned to a treatment condition.

A one-way ANOVA was conducted to determine whether the groups differed significantly on any demographic characteristics or pre-testing scores. Pre-treatment group characteristics on all variables are displayed in Table 1. There were significant differences between the three groups at pre-testing on two variables: reaction time from CVD, $F(3,54) = 8.30$, $p < 0.001$; and the EOW-E score, $F(3,54) = 4.91$, $p = 0.004$. Post-hoc testing using a Sidak correction indicated that the Bilingual treatment group scored significantly higher on the EOW-E than both the English treatment and deferred treatment control groups, and that the English treatment group was significantly slower than all other groups on CVD. These differences may be partially attributed to slight differences in age across the groups, which approached but did not reach significance ($F(3,55) = 2.17$, $p = 0.102$). In general, children in the bilingual group were slightly older than children in the English language group. Pre-treatment test scores were accounted for in determining the relative effectiveness of the different treatment conditions (see Analyses).

Treatment fidelity—Treatment fidelity was conducted via video recording. Trained research assistants not involved in the assessment or treatment phases of the study reviewed video recordings of 17 percent of all treatment sessions to verify that participants were engaged in the prescribed treatment activities for 75 minutes. For the nonlinguistic cognitive processing treatment, fidelity reviewers also coded the verbal output of the SLPs to ensure that they were not providing inadvertent linguistic cuing (in the form of recasts, expansions, or corrections) to participants. Reviewers were instructed to count any instance in which the clinician responded to a child utterance by providing additional or corrected semantic or syntactic information. Fidelity review verified that the number of such cues in the nonlinguistic cognitive processing treatment sessions was very low (M = 1.4, SD = 2.0).

In addition, a trained bilingual research assistant separately reviewed 21 percent of sessions for the bilingual treatment condition. Each thirty-second interval within the session was coded according to the language used by the SLP (i.e., Spanish, English, or both). Results of this review indicated that the SLP met the stated goal of at least 80% Spanish use in all sessions that were reviewed. The range of Spanish use in the sessions reviewed was 83% to 97%.

Attrition—An additional five children enrolled in the study but are not included in analyses here. Two of these children were assigned to a treatment group (one nonlinguistic cognitive processing, one bilingual), but then failed to participate in the after school or summer school programming in which treatment would be provided. In addition, three children participated partially in the treatment programs, but were not included in analyses due to poor attendance at treatment sessions (i.e., attendance at 12 or fewer treatment sessions). One of these children had been assigned to the English group, and two to a nonlinguistic cognitive processing group. Reasons for poor attendance for these few children included illness, transportation issues, or conflicts with scheduling for the after-school program.

Analyses

In all analyses of treatment effects, both standard and raw scores from norm-referenced language tests were included and are reported here. The use of either standard or raw scores alone presents a set of methodological concerns. For standard scores, three concerns can be noted: (1) the bilingual children in this study are not represented in the normative sample of the English standardized tests (EOW-E, ROW-E, and CELF-E); (2) standard scores for the Spanish vocabulary measures (EOW-S and ROW-S) are based on bilingual rather than Spanish-only administration; and (3) standard scores could underestimate the magnitude of change for participants in all groups, as participants in this study frequently scored below test norms (e.g., 24 participants received a standard score of <55 at pre-testing on the EOW-S; 15 participants received a standard score of 40 at pre-testing on the CELF-4E; see Table 1). However, raw scores also present disadvantages, as (1) raw scores are not readily meaningful or interpretable and (2) raw score are not comparable across ages or tests. We use both raw and standard scores here to mitigate the weaknesses of either score alone, and to provide converging evidence of treatment effects.

Two types of analyses were used to determine the effects of the treatment programs on each of the three domains of interest (nonlinguistic cognitive processing, Spanish, and English). First, matched-pairs *t*-tests were used to analyze within-group change from pre- to post-testing for each dependent variable. Counting raw and standard scores from standardized tests separately, there were a total of three nonlinguistic cognitive processing dependent variables (CVD, SSA, ASM), seven English dependent variables (EOW-E raw, EOW-E standard, ROW-E raw, ROW-E standard, CELF-E raw, CELF-E standard, and NWR-E), and seven Spanish dependent variables. The Spanish vocabulary measures (EOW-S and ROW-S raw and standard scores) were not analyzed for the control group because of the small number of children with Spanish-only pre- and post-test scores in this group. Thus, there were a total of 17 dependent variables and four groups, with four tests omitted, resulting in 64 comparisons. Due to the large number of tests performed, Benjamini and Hochberg's (1995) false discovery rate procedure was used to prevent Type I error. The false discovery rate was set at 0.10. For significant effects, an effect size (Cohen's *d*, Cohen, 1988) was calculated to index the magnitude of change resulting from treatment.

The second type of analysis was designed to address relative efficacy. Change scores (i.e., post-test score minus pre-test score) were calculated for each dependent variable. These change scores were compared across groups using Analysis of Covariance (ANCOVA), with the pre-test score used as the covariate (cf., Gillam et al., 2008). For significant effects, an effect size (η^2, or eta-squared) was calculated to index the proportion of variance in change scores accounted for by group membership.

Results

Absolute Effectiveness

Table 2 displays the pre- and post-testing scores on each dependent variable by group. It also indicates the statistical significance of each comparison and effect sizes for significant comparisons. Controlling the false discovery rate at 0.10 (Benjamini & Hochberg, 1995) resulted in p values at or below 0.034 reaching statistical significance. For the nonlinguistic cognitive processing treatment group, five comparisons reached statistical significance: EOW-E scores improved significantly for raw scores only (mean change of 4.6 raw points, $t = 3.02$, $p = 0.009$, $d = 0.29$); Core language composite scores on the CELF-4E improved by an average of 3.9 standard points ($t = 2.60$, $p = 0.020$, $d = 0.33$), or by 8.4 raw points ($t = 3.29$, $p = 0.005$, $d = 0.25$) ; Spanish NWR scores improved by 12.0 PPC points ($t = 2.61$, $p = 0.02$, $d = 0.54$); and mean reaction time on CVD decreased (improved) by an average of 62.7 milliseconds ($t = 2.71$, $p = 0.016$, $d = 0.78$). Using conventional interpretations of interpretations of Cohen's *d* (Cohen, 1988), these results suggest the nonlinguistic cognitive processing treatment resulted in small improvements in English expressive vocabulary and overall English language skills, medium improvements in Spanish NWR, and large improvements in processing speed.

For the English group, seven comparisons reached statistical significance. Scores on two English language tests improved, using both standard and raw scores: EOW-E score improved by an average of 7.2 standard points ($t = 5.76$, $p< 0.001$, $d = 0.82$) and 10.1 raw points ($t = 6.78$, $p< 0.001$, $d = 0.79$), and Core language composite scores from the CELF-4E improved by an average of 6.8 standard points ($t = 3.96$, $p = 0.001$, $d = 0.60$) and 17.1 raw points ($t = 6.93$, $p < 0.001$, $d = 0.45$). In addition, scores on all of the nonlinguistic cognitive processing scores improved significantly for this group; mean reaction time on the CVD task improved by an average of 101.9 milliseconds ($t = 3.38$, $p= 0.004$, $d= 0.71$), ASM task scores improved by an average of 0.82 points ($t = 2.64$, $p = 0.018$, $d = 0.46$), and d'

scores on the SSA task improved by an average of 0.62 (t = 2.68, p = 0.017, d = 0.52). The effect sizes associated with these gains indicate that the English language treatment led to large improvements in English vocabulary and medium improvements in overall English language skills as well as all nonlinguistic cognitive processing skills.

For the bilingual group, nine comparisons reached significance. On the English language measures, EOW-E score improved by an average of 4.3 standard points (t = 2.73, p = 0.017, d = 0.55) and by 5.7 raw points (t = 2.95, p = 0.011, d = 0.36), Core language composite scores from the CELF-4E improved by an average of 6.5 standard points (t = 2.81, p = 0.014, d = 0.72) and by 15.5 raw points (t = 2.81, p < 0.001, d = 0.50), and NWR-E scores improved by 7.1 PPC points (t = 2.47, p = 0.027, d = 0.76). In Spanish, EOW-S scores improved by an average of 5.1 standard points (t = 2.37, p= 0.032, d = 0.43) and by 7.1 raw points (t = 4.87, p <0.001, d = 0.61). Core language composite scores for the CELF-4S improved significantly for raw scores only, by an average of 4.9 raw points (t = 2.44, p = 0.028, d = 0.19). Finally, the bilingual group showed significant change on one of the nonlinguistic cognitive processing tasks, CVD. However, the change was not in the expected direction; the group average reaction time was 60 milliseconds slower after treatment than before, t = 3.92, p = 0.002, d = 0.43. The effect sizes for the bilingual treatment group indicate medium-sized gains in English NWR and overall English language skills, small- to medium-sized gains in English and Spanish expressive vocabulary, and small gains in overall Spanish skills. The significant decrease in performance on the processing speed measure represents a small effect.

For the deferred treatment control, two comparisons reached significance. Scores on the EOW-E improved using raw scores only (mean change of 6.5 raw points, t = 2.61, p = 0.028, d = 0.36). This group also improved performance on the SSA task by an average of 0.57 points on the d' measure (t = 3.27, p = 0.010, d = 0.46). Both effect sizes are considered small.

Relative Effectiveness

To compare the results of the three treatment programs to each other and to the no-treatment control, ANCOVA analyses were performed for each dependent variable using the pre-testing score for that variable as the covariate. This resulted in adjusted mean change scores, which are displayed by group in Table 3. Between group differences reached statistical significance for the raw scores from the CELF-4E, F= 4.96, p = 0.004, η^2= 0.103, although they did not reach significance using the standard scores from the same test. The η^2 effect size indicates that 10.3% of the variance in raw CELF-4E gains can be explained by group membership. In addition, mean reaction time for Choice Visual Detection differed significantly between groups, (F= 4.90, p = 0.004, η^2= 0.129), indicating that group membership accounted for 12.9% of the variance in CVD gains. For all remaining variables, the covariate-adjusted mean group change did not differ across groups at the p = 0.05 level.

Post-hoc testing was conducted to explore group differences on CELF-4E raw scores and on Choice Visual Detection. Sidak corrections were applied to p values to adjust for multiple comparisons. For CELF-4E raw scores, both the English treatment group and the bilingual group improved significantly more than the deferred treatment control group (English vs.

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control, p =0.011, d = 1.37; bilingual vs. control, p =0.027, d = 1.45), with large effect sizes. On the Choice Visual Detection task, the nonlinguistic cognitive processing group improved significantly more than the bilingual group (p<0.001, d = 1.27), again with a large effect size. The remaining group comparisons were not significant after controlling for multiple comparisons.

Discussion

The first question of interest is whether each of the three treatment programs produced gains in skill areas targeted most directly by that program (e.g., English skills for the English treatment group). In general, the absolute efficacy analyses suggest that change in targeted areas occurred. For the nonlinguistic cognitive processing treatment, participants improved processing speed significantly and improvements on sustained selective attention (the other skill treated directly) approached statistical significance. The English treatment group achieved statistically significant change, with moderate to large effect sizes, on two of four English language measures. Finally, the bilingual treatment group achieved treatment gains in both Spanish and English, although more of the English language gains reached statistical significance. These combined findings are consistent with highly interactive theories of language and cognition in bilingual learners (cf. Kohnert, 2013).

It is important to note that these analyses examine generalization of treatment gains within a directly treated domain, as in all cases the items and tasks used in pre- and post-treatment testing were not the same as those used in the treatment program. In each of the three treatment conditions, participants also improved their performance on treatment tasks, demonstrating learning of directly trained skills. For example, during the first week of treatment, children in the nonlinguistic cognitive processing group, on average, were able to complete 4.5 commands in the Bop-It game before making an error. By the final week of treatment, the group averaged 11.5 correct responses before making an error. Similarly, the English group was able to label 31.2% of categories in the Category Card Game during the first week of treatment. By the final week, the group averaged 75.7% correct labels on the same game.

These findings of learning on treatment tasks are consistent with previous work on treatment of vocabulary in bilingual children with PLI (Perozzi & Sanchez, 1992; Restrepo et al., 2012), in which children made substantial gains on treated exemplars. In this study, the additional statistically significant gains on some pre- and post-treatment assessments within the treated domain for each training condition extends past work. These gains indicate that bilingual children with moderate-severe PLI can generalize, to some extent, from treated to untreated exemplars within a general area addressed by treatment. Next, we consider whether treatment effects can extend beyond areas directly addressed by treatment.

Cross-linguistic and Cross-domain Transfer

The second question of interest is whether treatment effects generalized beyond the skill domain directly treated. This question can be further subdivided into examinations of cross-linguistic (L2 to L1) transfer and cross-domain (cognition to language, and vice versa) transfer. To examine cross-linguistic transfer, we considered the performance of the English language treatment group on Spanish language measures. The English language treatment group generally made small gains in scores on the Spanish language measures, with no gains reaching statistical significance. When pre-test score was co-varied out, the English language group performed comparably to or below the bilingual group on Spanish measures. Thus, our evidence suggests that providing treatment in L2 produces minimal effects in L1 for school-age children with PLI. This result is consistent with the limited literature comparing English language treatment to bilingual treatment for younger bilingual children with PLI (Perozzi & Sanchez, 1992; Restrepo et al., 2012).

On the other hand, children in the bilingual treatment made significant gains in English. The interpretation of these results is more speculative, given that English was used to some extent within the bilingual sessions and, as with participants in other treatment conditions, English was the primary language of the larger educational setting. The English gains in the bilingual group are consistent with the general trend towards larger English gains across groups. However, cross-linguistic transfer from L1 to L2 could also have played a role in the English gains seen in the bilingual treatment group.

In terms of cognitive to linguistic transfer, the performance of the nonlinguistic cognitive processing group on the English and Spanish language measures provides evidence that treatment based entirely on improving nonlinguistic cognitive processing skills can positively influence language skills in children with PLI. The nonlinguistic cognitive processing group made significant gains from pre- to post-treatment testing on the Core Language score of the CELF-4E and on the NWR task in Spanish. The case for cognition-to-language skill transfer is tempered somewhat by the findings that gains in language for this group did not extend to all language measures, and that on most measures the two groups who received direct treatment on language skills made larger gains than the nonlinguistic cognitive processing group. However, even small changes in the language system following a nonlinguistic treatment protocol support connections between nonlinguistic cognitive processing and language skills, consistent with general cognitive theories of language.

In addition, there is some evidence of transfer to both L1 and L2, as would be predicted if nonlinguistic cognitive processing skills are related to language learning deficits in both languages of bilingual children with PLI. Gains in L1 (Spanish) were largely restricted to the NWR measure for this group. However, the lack of more widespread change in Spanish is consistent with the overall trend across all groups (see **Supporting L1** below).

Finally, we consider the possibility of cross-domain transfer in the opposite direction, or transfer from treated language skills to cognitive processing skills. Results here are mixed. While the English language group made statistically significant change from pre- to post-treatment testing across all three nonlinguistic cognitive processing measures, the bilingual treatment group did not. In fact, the bilingual treatment group had a significant decrement in performance from pre- to post-treatment testing on CVD. This contradictory pattern of results may stem from the pre-treatment differences in groups. Prior to treatment, the English language group was substantially slower on CVD; the group also tended to be younger and perform more poorly on SSA and ASM, although these differences did not reach significance. The gains experienced by the English language group may thus be at least in part an artifact of their poorer performance at the starting point, particularly as raw scores were used on these experimental measures.

In addition, the data across groups on the SSA task suggest that the task may have been an imperfect measure of the skill of interest within this group of children; participants demonstrated an unexpectedly high degree of accuracy on the task at pre-treatment testing, and post-treatment gains appear largely dependent on group pre-treatment performance (i.e., groups with lower pre-test scores made larger gains on the task). However, it also remains possible that the act of engaging actively in an intensive language treatment program improves attention (e.g., Gillam et al., 2008; Stevens et al., 2008), and perhaps working memory and processing speed as well. Further work in this area is needed to explore the effects of language treatment on general cognitive processing mechanisms.

Supporting L1

A notable trend across all groups is smaller gains in Spanish than in English. Even the bilingual treatment group, whose treatment was primarily in Spanish, made substantial gains from pre- to post-treatment testing on more English measures than Spanish measures. As discussed above, there was modest evidence of transfer to Spanish for the English language group, and less evidence of transfer in Spanish than in English for the nonlinguistic cognitive processing group. This overall trend may reinforce previous case reports of plateaus, or even decline, in L1 in the absence of treatment for children in this age group (e.g., Restrepo & Kruth, 2000). The greater English gains in this study may also partially reflect the influence of direct educational instruction, as participants were presumably learning new classroom vocabulary in English.

Thus, both the social and educational contexts for these school-aged bilingual children support growth in English but not in Spanish. Treatments designed to support Spanish go against the typical growth pattern, making even small gains harder to obtain (and thus, perhaps, more meaningful). These results underscore the need for continued active support for L1 in minority language learners with PLI. Viewed from the opposite perspective, the results also support the conclusion that SLP treatment can boost L2 gains, even when treatment does not take place entirely in L2.

Limitations and Future Directions

The gains produced from pre- to post-treatment testing across all treatment groups were relatively modest; in most cases, gains for children in active treatment groups were not statistically different than gains for children in the deferred treatment control (who received school-based but not experimental treatment services). It should be noted, however, that the magnitude of pre- to post-testing gains seen here is comparable to that reported in other treatment studies involving children with PLI in this age range (e.g., Gillam et al., 2008). That is, the limited treatment literature for school-aged children with PLI suggests that change is relatively slow, at least when measured by standard scores on norm-referenced tests. Examination of gains on tasks completed during treatment sessions (e.g., *Bop-It* and *Category Card Games*) yields larger numbers, but provides less evidence of systemic language change. Thus, we focused our analyses on general measures of language and cognitive ability.

Statistical significance in this study was also affected by the sample size, particularly for the deferred treatment control group, and by the heterogeneity endemic within any group of bilingual children with PLI (e.g., Kohnert, 2010). For example, although we included only children who spoke primarily Spanish at home and English at school, variation within these parameters was inevitable. It may be productive to consider individual characteristics as starting points for future exploration of what drives treatment effectiveness. Examination of the effect of variables such as age, initial severity, and language background on treatment outcomes may expand the clinical knowledge base more than attempts to obtain homogeneous samples of bilingual children with PLI.

Similarly, the range of treatment sessions completed by children in an active treatment group was relatively large (13 to 24), although the overall intensity of the treatment (up to four 90-minute sessions weekly) was relatively high for all children. To date, there is minimal data on optimal intervention dosage for children with PLI. Further examination of any variation in outcome that can be attributed to treatment attendance may provide an indication of whether children with PLI make increasing gains when given increasing numbers of treatment sessions.

Finally, the ultimate goal of treatment for children with PLI is long-term, rather than immediate, language growth. In particular, the hypothesis that improvement in cognitive processing skills could alter language *learning* ability warrants an examination of language growth following the completion of treatment. Follow-up examination of language change after treatment may provide additional support for one or all of the treatments examined here.

Summary and Conclusions

The data here provide some support for SLPs working with bilingual children with PLI. They indicate that computer and interactive treatment activities do improve English language skills to a significant degree. Gains in English can also be obtained through bilingual treatment activities, and (albeit to a lesser degree) through addressing cognitive processing skills. Gains in Spanish are more difficult to obtain, and most likely to occur when Spanish is directly addressed in treatment -- perhaps through the use of select computer programs in Spanish, SLP-mediated peer interactions, and consultation with bilingual professionals and paraprofessionals. Finally, gains in processing speed can be obtained through directly treating processing speed and perhaps through language-based activities as well. Bilingual children with PLI may ultimately benefit most from treatments designed to support all three keys areas of development: L1, L2, and cognitive processing skills.

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Table 1

Participant characteristics at enrollment, by treatment condition.

Variable	Nonlinguistic Cognitive Processing (n = 16)	English Language (n = 17)	Bilingual (n = 15)	Control(n=11)
Age	8;5 (1;4)	7;10 (1;6)	9;0 (1;3)	8;9 (1;6)
TONI	96.6 (16.1)	92.5 (9.7)	92.4 (9.2)	87.6 (6.8)
ROW-E	76.1 (5.1)	73.4 (5.1)	78.5 (9.1)	73.3 (7.4)
EOW-E	64.9 (6.4)	61.1 (7.4)	69.3 (7.8)	60.5 (4.7)
CELF-E	49.9 (9.9)	47.8 (9.4)	52.7 (8.4)	45.3 (6.3)
NWR-E	53.2% (17.4)	53.4% (15.7)	58.0% (7.5)	50.5 (16.6)
ROW-S	73.9 (10.7) [n=10]	70.2 (14.5) [n = 11]	68.9 (18.0)	65.2 (16.9) [n =6]
EOW-S	66.7 (15.7) [n=10]	68.6 (20.1) [n =11]	61.0 (8.1)	65.4 (13.9) [n=7]
CELF-S	59.7 (11.6)	64.8 (13.0)	60.3 (9.4)	56.2 (10.7)
NWR-S	62.8% (24.9)	63.7% (25.7)	78.0% (10.4)	65.0 (26.3)
CVD	708.8 (79.1)	857.0 (148.1)	684.0 (133.9)	661.6 (93.2)
SSA	3.7 (1.0)	3.1 (1.3)	3.8 (0.9)	3.3 (1.1)
ASM	2.5 (1.6)	1.8 (1.8)	2.6 (1.5)	1.6 (1.6)

Note. For all variables, the group mean is displayed, with standard deviation in parentheses. Ages are listed as year;month. For nonverbal intelligence, expressive vocabulary, receptive vocabulary, and core language testing, standard scores are displayed for ease of interpretation. For nonword repetition tasks, Percent Phonemes Correct for the longest syllable length is displayed. Mean reaction time in milliseconds is displayed for Choice Visual Detection; highest task level with 11 of 15 items correct is displayed for auditory serial memory; and *d′* is displayed for the sustained selective attention task. Abbreviations are as follows: TONI = Test of Nonverbal Intelligence, 3rd Edition; ROW-E = Receptive One-Word Vocabulary Test (English); EOW-E = Expressive One-Word Vocabulary Test (English); CELF-E = Clinical Evaluation of Language Fundamentals-4th Edition, English, Core Language Score; NWR-E = English Nonword Repetition; ROW-S = Receptive One-Word Vocabulary Test, Bilingual Edition (Spanish); EOW-S = Expressive One-Word Vocabulary Test, Bilingual Edition (Spanish); CELF-S = Clinical Evaluation of Language Fundamentals-4th Edition, Spanish, Core Language Score; NWR-S = Spanish Nonword Repetition; CVD = Choice visual detection; SSA = Sustained selective attention; ASM = Auditory Serial Memory.

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Table 2

Pre- and post-testing performance and significance of change on English, Spanish, and nonlinguistic cognitive processing measures as a function of treatment condition.

	NCP				English				Bilingual				Control			
	pre	post	*p*	*d*	pre	post	*p*	*d*	pre	post	*p*	*d*	pre	post	*p*	*d*
ROW-E	76.1	77.9	0.306	0.30	73.4	76.4	0.089	0.43	78.5	81.9	0.073	0.41	73.3	74.1	0.588	0.18
	62.1	65.3	0.204	0.31	53.7	58.1	0.064	0.31	68.4	73.1	0.044	0.28	57.2	59.70	0.375	0.20
EOW-E	64.9	67.1	0.084	0.26	61.1	68.3	<0.001*	0.82	69.3	73.6	0.017*	0.55	60.5	64.6	0.068	0.60
	44.2	48.8	0.009*	0.29	35.8	45.8	<0.001*	0.79	54.4	60.1	0.011*	0.36	36.5	43.00	0.028*	0.36
CELF-E	49.9	53.8	0.020*	0.33	47.8	54.7	0.001*	0.60	52.7	59.2	0.014*	0.72	45.3	46.4	0.237	0.16
	61.7	70.1	0.005*	0.25	47.1	64.2	<0.001*	0.45	74.9	90.5	<0.001*	0.50	54.7	58.27	0.335	0.10
NWR-E	53.2	54.1	0.819	0.05	53.4	56.4	0.383	0.19	58.0	65.2	0.027*	0.76	50.5	52.5	0.806	-0.10
ROW-S	73.9	74.1	0.970	0.01	70.2	70.3	0.980	0.01	68.9	71.7	0.479	0.17	--	--	--	--
	58.5	55.3	0.640	-0.18	47.0	48.2	0.730	0.07	46.9	56.6	0.059	0.48	--	--	--	--
EOW-S	66.7	68.0	0.649	0.08	68.6	73.1	0.179	0.21	61.0	66.1	0.032*	0.43	--	--	--	--
	33.8	35.7	0.450	0.14	32.7	35.3	0.247	0.24	28.5	35.6	<0.001*	0.61	--	--	--	--
CELF-S	59.7	59.6	0.954	0.00	64.8	67.0	0.222	0.16	60.3	62.5	0.183	0.22	56.2	57.6	0.505	0.14
	53.3	56.3	0.309	0.10	52.3	59.5	0.038	0.20	54.2	59.1	0.028*	0.19	47.0	52.18	0.173	0.17
NWR-S	62.8	74.8	0.020*	0.54	63.7	67.5	0.541	0.17	78.0	74.0	0.113	−0.36	65.0	65.5	0.94	0.02
CVD	708.8	646.1	0.016*	0.78	857.0	755.1	0.004*	0.71	684.0	744.4	0.002*	−0.43	661.6	673.6	0.703	0.15
SSA	3.7	4.0	0.097	0.34	3.1	3.7	0.017*	0.52	3.7	4.1	0.084	0.45	3.3	3.9	0.01*	0.46
ASM	2.5	2.8	0.300	0.15	1.8	2.6	0.018*	0.46	2.6	2.9	0.364	0.19	1.6	2.3	0.224	0.37

Note. Table displays the group means before and after treatment for unadjusted scores. For standardized tests (ROW, EOW, CELF), raw scores are listed in rows with gray shadow and standard scores in rows without shadow. The control group was omitted from the ROW-S and EOW-S analyses due to small group size for those variables. Positive *d* values indicate improvement from pre- to post-testing. See Table 1 Note for descriptions of variables and a list of abbreviations.

* indicates comparisons that reached significance after controlling the false discovery rate at 0.10 (Benjamini & Hochberg, 1995).

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Table 3

Comparison of pre- to post-treatment change scores across treatment conditions, adjusted for pre-test score.

Variable	Score Type	NCP	English	Bilingual	Control	*p*	η^2
ROW-E	Std	2.22	1.97	4.94	−0.02	0.269	
	Raw	3.67	2.26	7.29	1.47	0.275	
EOW-E	Std	2.21	7.11	4.41	4.11	0.108	
	Raw	4.60	9.89	5.99	6.35	0.181	
CELF-E	Std	3.91	6.75	6.66	0.88	0.117	
	Raw	8.44	16.71	15.97	3.41	0.004	0.103
NWR-E		0.10	2.30	9.00	−1.80	0.122	
ROW-S	Std	1.86	−0.16	1.88	XX	0.901	
	Raw	0.72	−0.29	8.20	XX	0.322	
EOW-S	Std	1.46	4.87	4.72	XX	0.626	
	Raw	2.41	2.84	6.51	XX	0.213	
CELF-S	Std	−0.17	2.63	2.16	0.88	0.560	
	Raw	3.05	7.19	5.03	4.96	0.773	
NWR-S		9.10	1.50	2.80	−1.00	0.185	
CVD		74.82	51.94	−37.93	19.81	0.004	0.129
SSA		0.40	0.48	0.51	0.49	0.971	
ASM		0.35	0.71	0.40	0.48	0.821	

Note. Table displays the mean change score (i.e., post-test score minus pre-test score) for each group and outcome measure, with the pre-test score for that measure co-varied out. For standardized language tests, both standard and raw score changes are listed. The control group was omitted from the ROW-S and EOW-S analyses due to small group size for those variables. *P* values indicate the significance of the ANCOVA analysis comparing the four groups' change scores. See Table 1 Note for descriptions of variables and a list of abbreviations.