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Article

# Complexity and cross-linguistic transfer in intervention for Spanish–English bilingual children with speech sound disorder

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## Abstract

With bilingual children, intervention for speech sound disorders must consider both of the child's phonological systems, which are known to interact with each other in development. Further, cross-linguistic generalization following intervention for bilingual children with speech sound disorders (i.e. the impact of treatment in one language on the other) has been documented to varying degrees in some prior studies. However, none to date have documented the cross-linguistic impact of treatment with complex targets (e.g. consonant clusters) for bilingual children. Because complex phonological targets have been shown to induce system-wide generalization within a single language, the potential for bilingual children to generalize learning

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**across languages could impact the efficiency of intervention in this population. This pilot intervention study examines the system-wide, cross-linguistic effects of treatment targeting consonant clusters in Spanish for two Spanish–English bilingual children with phonological disorder. Treatment was provided with 40-minute sessions in Spanish via teletherapy, three times per week for six weeks. Comprehensive phonological probes were administered in English and Spanish prior to intervention and across multiple baselines. Pre-intervention data were compared to data from probes administered during and after intervention to generate qualitative and quantitative measures of treatment outcomes and cross-linguistic generalization. Results indicate a medium effect size for system-wide generalization in Spanish (the language of treatment) and English (not targeted in treatment), for both participants (mean effect size in Spanish: 3.6; English 4.3). These findings have implications for across-language transfer and system-wide generalization in treatment for bilingual children.**

Keywords: bilingualism, speech sound disorder, phonological disorder, language transfer, treatment

## Background

Speech sound disorders are the most prevalent communication impairment affecting pre-school and early school-age children (Black et al., 2015; Law et al., 2000). Consequently, children with speech sound disorders predominate speech-language pathologists' caseloads, particularly in primary school settings (Baker & McLeod, 2004; Brumbaugh & Smit, 2013; Joffe & Pring, 2008; Mcleod & Baker, 2014; Mullen & Schooling, 2010; Priester et al., 2009). It is also the case that interventions for speech sound disorders can have measurable positive impact on relevant language outcomes (i.e. production accuracy, intelligibility; Law et al., 2004) and far-reaching socioeconomic outcomes (i.e. social and academic attainment; King et al., 1982; Kwiatkowski & Shriberg, 1993; Shriberg, Gruber, et al., 1994; Shriberg, Kwiatkowski, et al., 1994) for children with speech sound disorders. However, the presence of effective treatment does not equal optimal treatment, nor does it imply equitable access to treatment. Indeed, many children with speech sound disorders face barriers to optimal intervention, especially those children who are bilingual or use languages other than English (e.g. Heilmann & Bertone, 2021).

### *Treatment for phonological disorder*

The most widely implemented treatments may not reflect best practices for many children with speech sound disorders. Consider that the most common speech sound disorders are phonologically based impairments, which may be referred to as phonological disorder (PD; e.g. Dodd et al., 1989; Hewlett, 1985; Shriberg & Kwiatkowski, 1982a), phonological delay (e.g. Dodd et al., 2018; Gierut et al., 1994; cf. Waring et al., 2022), or functional phonological disorder (e.g. Gierut, 1998b; Gierut & Morrisette, 2012) in the extant literature. The unifying deficit in PD is functional impairment of the development, manipulation, retrieval or production of phonological structures, resulting in protracted or atypical speech sound acquisition and low speech intelligibility (Gierut, 1998b; Shriberg & Kwiatkowski, 1994). Globally, the most frequently employed treatment approach for children with phonologically based speech sound disorders is traditional articulation therapy (Hegarty et al., 2018; Mcleod & Baker, 2014; Oliveira et al., 2015; Skahan et al., 2007), despite evidence which indicates that PD is more effectively remediated through phonological approaches (e.g. Dodd & Bradford, 2000; Lousada et al., 2013). When speech-language pathologists use treatment methodologies to address impairments for which they are not indicated, they are not providing optimal intervention for those impairments. Consequently, business-as-usual intervention may itself present a barrier to optimal intervention for PD.

### *Phonological complexity in treatment*

Many alternatives to traditional therapy approaches have been studied in the literature, including minimal pairs intervention (Baker, 2010), metaphonological intervention (Hesketh, 2010), nonlinear phonological intervention (Bernhardt et al., 2010), speech perception intervention (Rvachew & Brosseau-Lapré, 2010), cycles phonological remediation (Prezas & Hodson, 2010), and complexity-based treatment target selection (Baker & Williams, 2010). Of these, complexity-based target selection (Gierut, 2007) is an approach associated with broad generalization beyond the structure targeted in treatment, per a recent meta-analysis (Maggu et al., 2021). The presumed active ingredient in this approach is the selection of relatively complex phonological structures, which have been operationalized differently across studies, often as developmentally later-acquired consonants or consonant clusters or structures absent from a given child's sound system, produced with little-to-no accuracy (Gierut, 2007; Morrisette et al., 2006). Per this approach, introducing a new, relatively complex structure into a child's phonological system stimulates change or expansion to accommodate the new input (Gierut, 2007; Storkel, 2018). These changes are motivated by converging theories of language acquisition (e.g. Wexler, 1982) and markedness (e.g. Tesar & Smolensky, 1998). Markedness defines the complexity of a treatment target based on such characteristics as the frequency of occurrence of a sound structure across the world's languages (i.e. less common sounds are more marked and more complex). Implicational relationships define obligatory occurrences of certain sound structures based on the presence of other marked structures (e.g. a language system that includes marked fricative consonants must also include unmarked stop consonants).

These widely attested relationships predict specific changes that are expected to occur following treatment with a given speech target. For example, fricative consonants are *marked* relative to stop consonants. Thus, languages that use fricatives are expected to also use stops. Stated differently, the presence of fricatives in a system *implies* that stops must also be present. Given these, treatment targeting a fricative /z/ is expected to improve other fricatives in the sound system (e.g. /f/, /v/, /s/) as well as stops (e.g. /g/, /k/, /d/, /t/, /b/, /p/), but not necessarily liquids, nasals, or consonant clusters that do not contain /z/. Via this mechanism, targeting one complex structure can indirectly affect other aspects of a child's sound system (i.e. broad generalization; Elbert et al., 1984; Gierut, 1990, 1998a, 1999; Gierut et al., 1996; Gierut & Morrisette, 2012; Maggu et al., 2019, 2021; Pagliarin et al., 2009; cf. Rvachew & Nowak, 2001); however, some operationalizations of complexity, particularly those that relate to a child's presenting knowledge of a speech target, may not consistently result in the same degree of broad generalization (Elbert et al., 1984; Elbert & McReynolds, 1979; Flint & Ingham, 2005; Gierut, 1991; Gierut et al., 1987; Gierut & Neumann, 1992; Powell et al., 1991; Rvachew & Bernhardt, 2010; Rvachew & Nowak, 2001; Williams, 1991).

### *Barriers to implementation and access*

Despite potential as an implementable strategy for improving treatment outcomes for the most prevalent type of speech sound disorder, significant barriers prevent implementation of a complexity-based approach, which is reflected in clinical practice trends. For instance, an estimated 8% of speech-language pathologists reported giving high priority to complexity-based target selection, as compared to 70% who reported high priority for traditional target selection (Mcleod & Baker, 2014). Infrequent implementation of this approach is likely related to multiple factors, including but not limited to a lack of awareness of this approach among practising speech-language pathologists and obstacles to accessible target selection procedures (Hegarty et al., 2018). Even with increased awareness, speech-language pathologists are more likely to maintain practices they have already used than to adopt new approaches (Joffe & Pring, 2008). Existing complexity-based target selection guidelines can also require a time commitment that may not be sustainable for many clinicians (Combiths, 2022b). However, recent evidence (Combiths, 2022a; Potapova et al., 2022), including from school-based (Combiths et al., 2019; Taps Richard et al., 2017) and teletherapy interventions (John et al., 2022) suggests that simplified procedures which emphasize targeting phonologically complex consonant clusters (e.g. /fl-/) over singleton consonants (e.g. /l/) can yield substantial generalized phonological growth. This presents a promising avenue for streamlined implementation, as clinicians could be directed to target one of many consonant cluster structures that a child has not yet acquired.

A lack of general awareness and procedural guidance creates barriers to implementation of complexity-based target selection, but there is an even greater obstacle that differentially restricts children with minoritized language profiles from accessing optimal evidence-based treatment. This is due to the paucity of speech treatment research in populations other than monolingual English-speaking children. Between 1950 and 2018, Fabiano-Smith and Cuzner (2018) estimated that only 20 peer-reviewed research studies published in English have explicitly included bilingual children with speech sound disorders. The lack of linguistic diversity in the extant investigations of treatment for speech sound disorders is a critical issue. In accepting evidence which samples nearly exclusively from a homogeneous population, the fundamentally flawed assumption is that children with minoritized profiles are being appropriately served by research that does not include them or address their unique language systems. Without evidence to guide target selection in populations other than monolingual English-speaking children with PD, there is functionally an insurmountable obstacle to optimal treatment access for everyone else.

Globally, Spanish is spoken as a native language by more than 477 million people (Fernández Vítores, 2017), yet there is relatively little evidence to guide optimal target selection for Spanish-speaking children with speech sound disorders. Two case studies have targeted complex consonant clusters in Spanish-speaking children in the United States (Anderson, 2002; Barlow, 2005). In both studies, phonological improvement was documented in the treatment target and across untreated consonant clusters and singleton consonants as measured by growth in the phonetic inventory and improved production accuracy, consistent with previous results from treatment targeting clusters in English. Combiths et al. (2022a) examined the system-wide impact of phonological treatment targeting different types of complex structures in Spanish for Spanish–English bilingual children with PD. The four children in this study improved production of their targeted structures and demonstrated growth across their phonological systems via improved intelligibility and accuracy of untargeted monitored structures. Also consistent with predictions of complexity-based target selection, the two children with complex consonant cluster targets demonstrated greater treatment generalization across their Spanish phonological systems (i.e. standard mean difference [SMD] effect sizes of 8.5 and 1.5) than the two children with singleton targets (i.e. SMD effect sizes of 0.8 and 0.2). These findings suggest that treatment targeting complex clusters in Spanish can trigger widespread growth for Spanish–English bilingual children with PD. Although these studies support the efficacy of targeting complex clusters in treatment for Spanish–English bilingual children with PD, they do not address the unique influences of bilingualism or any cross-linguistic effects that may have occurred in treatment.

### *Bilingual language transfer*

Despite its disproportionately small representation in clinical research, bilingualism is the norm, rather than the exception, worldwide (Chakraborty, 2015). A primary question of interest for any speech or language treatment involving bilingual children is how knowledge and skills might transfer across a child's languages. A productive debate has surrounded the psycholinguistic representation of two languages in bilingual individuals, and much of this discussion centres around the question of whether bilinguals use a single unified language system or separate systems to represent their languages (Genesee, 1989; Volterra & Taeschner, 1978). In summary of a complex discussion rich with nuance, there is evidence to support the claim that bilinguals can have separate language systems by two years of age (Gathercole et al., 2014), or at least maintain the ability to distinguish components of separate systems within a unified organizational structure (Curtin et al., 2011). Thus, bilingual children are able to simultaneously represent two languages in such a way that the two distinct, or at least functionally distinguishable, systems can and do interact to varying degrees (e.g. Fabiano-Smith & Barlow, 2010).

#### *Language transfer in typical development*

The interaction between languages in bilinguals, often referred to as across-language (or cross-linguistic) transfer, is a dynamic and individualized phenomenon influenced by a diversity of factors. At present, more is known about language transfer in the context of typical second language acquisition than in the more specific context of speech or language impairment (Han, 2020). In the literature on second-language acquisition, the influence of one language, often the first language (L1), on development of a second language (L2) has been categorized as either *positive transfer* (i.e. acceleration) or *negative transfer* (i.e. deceleration) (Barlow, 2002; Core & Scarpelli, 2015; Fabiano & Goldstein, 2005; Fabiano-Smith & Barlow, 2010; Fabiano-Smith & Goldstein, 2010; Flege & Davidian, 1984; Goldstein & Bunta, 2012; Han, 2020; Lleó, 2016; Marecka et al., 2020; Sparks et al., 2009) based on the perceived influence of the L1 on the rate of development or accurate use of linguistic structures in the L2 (e.g. Goldstein & Bunta, 2012). However, positive and negative transfer are not clearly distinct processes (Gass & Selinker, 1994; Khvtisiashvili, 2018), and such classifications rely on subjective and perhaps inappropriate comparison of bilingual development to monolingual development, carrying with it an implicit assumption that monolingual development is the de facto standard for comparison. To avoid this subjectivity, positive, negative, and everything in between are included in the broader concept of language transfer (e.g. Gass & Selinker, 1994).

Many factors can impact the direction, nature, and extent of language transfer; those frequently implicated in the literature are shown in Table 1. One consideration is order of acquisition or the ages at which the two languages of a bilingual individual are acquired; sequential bilinguals are more likely to demonstrate transfer from the L1 to the L2, and the age at which the L2 is acquired can affect both the direction of transfer and the likelihood of acceleration or deceleration effects (e.g. Blom & Paradis, 2015). Similarly, the amount and context of exposure to each of a bilingual's languages, as well as

**Table 1.** Influential factors in bilingual language transfer.

| Influential factor | Effect | Selected references |
|---|---|---|
| Order of acquisition | Directionality, likelihood of positive/negative transfer | Barlow (2014); Blom and Paradis (2015); Flege (1987, 1995); Kohnert et al. (2005); Leeuw et al. (2010); Montrul (2008); Pham et al. (2015); Schlyter (1993) |
| Contexts and quantity of exposure and use | Likelihood of positive/negative transfer | Blom et al. (2012); Blom and Paradis (2015); Cummins (1978, 1979, 1980, 1981, 1991); Kehoe and Havy (2019); McLeod et al. (2021); Sun et al. (2022); Xie et al. (2022) |
| Proficiency | Directionality, likelihood of positive/negative transfer | Flege (1987); Leeuw et al. (2010); Montrul (2008); Schlyter (1993) |
| Dominance | Directionality, likelihood of positive/negative transfer | Argyri and Sorace (2007); Ball et al. (2001); Flege (1987); Leeuw et al. (2010); Montrul (2008); Schlyter (1993) |
| Typological similarities in L1/L2 | Likelihood of positive/negative transfer | Bohnacker (2006); Borodkin et al. (2022); Keffala et al. (2018); Kehoe and Havy (2019); O'shannessy (2011); Oshita (2004); Tessier et al. (2013) |
| Overlap of L1/L2 linguistic structures | Likelihood of positive/negative transfer | Bohnacker and Rosén (2008); Burrows et al. (2019); Fabiano-Smith et al. (2015); Fabiano-Smith and Barlow (2010); Fabiano-Smith and Goldstein (2010); Pérez-Leroux et al. (2011) |
| Metalinguistic skills and cognitive processes | Likelihood of positive/negative transfer, ultimate attainment | Bialystok (1988, 2001); Flynn et al. (2004); Foursha-Stevenson and Nicoladis (2011); Geva and Ryan (1993); Kuo et al. (2016); Kuo and Anderson (2010, 2012); Marinova-Todd et al. (2010) |

relative proficiency and dominance in each can affect the direction and nature of transfer. In simplified terms, when a bilingual is highly proficient, dominant, and/or has rich exposure to a language, that language is more likely to transfer elements or related skills to the relatively less proficient, dominant, or experienced language (Paradis et al., 2021). This transfer can result in acceleration or deceleration of acquisition of the other language, and characteristics of the two languages impact which type is more likely to occur.

When languages are typologically similar (e.g. shared syllable shapes, word order preferences, or tense and mood distinctions) or they share similar structures (e.g. shared phonemes, morphemes, or lexemes), there is more likely to be facilitative transfer overlapping grammatical rules or structures across languages (e.g. Fabiano-Smith & Goldstein, 2010; Keffala et al., 2018). In either case, dissimilarity is more likely to result in the opposing, decelerating effect. Furthermore, these patterns have considerable nuance and are not obligatory rules; thus, exceptions to these trends are frequent. For instance, when structures across languages are similar but not identical, it can result in a particular type of interference described as *equivalence classification*, in which a structure from one language is used as a substitute for the similar structure in the second language (Flege, 1995; Flege & Bohn, 2021).

Transfer is not limited to questions of shared features or dissimilarity of linguistic structures across languages. There is evidence to suggest that metalinguistic abilities, language learning skills, or psycholinguistic processes can be transferrable across languages. Flynn, Foley and Vinnitskaya (2004) provide evidence from third-language (L3) acquisition to describe the cumulative nature of language acquisition such that any prior language experience can have a net positive effect on L2 or L3 acquisition. This aligns with evidence that strong L1 acquisition of any language supports strong L2 acquisition (Kohnert et al., 2005). In other words, many skills are developed during acquisition of one language, and these tend to support acquisition of a second language.

### *Language transfer in speech intervention*

Research directly examining across-language transfer in treatment for bilingual children with speech sound disorders is sparse and primarily examines transfer of specific, directly targeted structures or processes that are shared across languages. Several studies have targeted production of phonological structures (e.g. /s/; Holm et al., 1997; Holm & Dodd, 2001), word positions or syllable shapes (e.g. medial and final consonants; Gildersleeve-Neumann & Goldstein, 2015) or elimination of phonological processes (e.g. gliding; Rossouw & Pascoe, 2018) in one or both of a bilingual child's languages, documenting improvement in targeted areas across languages, when those areas are similar or shared across those languages.

Notably, existing cross-linguistic treatment research has most frequently targeted the L2 in treatment, namely English (Holm et al., 1997; Holm & Dodd, 2001; Ray, 2002), or, in one study, the L1 (isiXhosa) in the context of otherwise L2 English sessions (Rossouw & Pascoe, 2018). Two studies targeted both of a bilingual child's languages (Portuguese/English; Ramos & Mead, 2014; and Spanish/English; Gildersleeve-Neumann & Goldstein, 2015) with subsequent across-language growth observed, although treatment provided in both languages is a confound to observing the directionality of language transfer. More recently, Nye (2019) examined cross-linguistic transfer in four Spanish–English bilingual children with speech sound disorders following treatment targeting a variety of individual phonological structures (e.g. /ʧ/), word shapes (e.g. four-syllable words), and phonological processes (e.g. stopping). As with previous studies, improvement was measured in the targeted structure in the treated language and via transfer to shared structures in the non-treated language. Thus, there is precedent for cross-linguistic transfer of treatment effects when a structure or process is similar or shared across languages in bilingual children with speech sound disorders. This notwithstanding, research on across-language transfer in treatment contexts is still in its early stages, and many questions remain unanswered. There has yet been no examination of across-language transfer of broad phonological change, such as has been implicated in complexity-based treatment (Maggu et al., 2019).

### *Current study*

This exploratory study addresses barriers to optimal intervention for bilingual children with PD by examining the efficacy of using straightforward complexity-based target selection procedures (i.e. selecting consonant clusters) as treatment targets in Spanish via teletherapy with two Spanish–English bilingual children with PD. Furthermore, elements of single-case design with multiple baselines are employed to examine the impact of intervention on generalized learning outcomes in both Spanish and English to identify the presence or absence of transfer in the form of broad, system-wide phonological generalization across languages.

## Method

The study described herein is part of an NIH-funded clinical trial (clinicaltrials.gov, No. NCT03977701) and was approved by the Institutional Review Board and Human Subjects Protection Program at San Diego State University. Study procedures were explained to parents and participants through a video call. Parents of participants then provided written informed consent, and the participants assented to participation.

### Participants

Two participants in this study were recruited through announcements posted online for a larger, ongoing treatment study. Both participants are Spanish–English bilingual children living in the United States, exposed to Spanish from birth and living in households with one or more Spanish-dominant caregivers who speak a Mexican variety of Spanish. Participants were enrolled concurrently in the study during the summer, and they did not receive any other speech or language services during the study intervention.

Lydia (age 5;2 at study onset) is a Hispanic/Latina girl, reported by her caregiver to use primarily Spanish at home and both Spanish and English in preschool, which she has attended since she was 4 years old. Her mother has a graduate degree. Julia (age 6;5 at study onset) is also a Hispanic/Latina girl, reported to use primarily English at home with her parents and in school, and Spanish with her grandmother, who is her caretaker during the day when not in school (e.g. during summer). Her mother has an undergraduate degree. Both participants have PD, identified using a converging approach (Restrepo, 1998), as follows. Caregivers of both participants reported concern with their child's speech development and low intelligibility, converging with absence of 10 or more consonants or consonant clusters from their phonetic or cluster inventories in both Spanish and English (e.g. Combiths et al., 2022a) and confirmed by the study speech-language pathologist. Using the 5-point Intelligibility in Context Scale (McLeod, 2020; McLeod et al., 2012), Lydia's mother reported her average Spanish intelligibility across contexts and conversation partners at 3.8 and in English at 3.0. Julia's mother reported 3.0 in Spanish and 4.4 in English using the same scale. Parents of both participants reported no developmental concerns outside of speech production.

### Study procedures

Two complementary case studies are described which incorporate elements of multiple-baseline, single-case design to establish the relationship between treatment and measurement of phonological change across languages (Byiers et al., 2012; Kratochwill et al., 2010; McReynolds & Kearns, 1983). Assessment and treatment sessions were conducted entirely online. Participants completed assessment and intervention activities via video call (using Zoom) with a Spanish–English bilingual speech-language pathology graduate clinician under the supervision of a licensed speech-language pathologist. Participants' caregivers completed language experience and developmental history questionnaires, and the Intelligibility in Context Scale via Qualtrics and over the phone. Participants received a portable audio recorder and were provided with instructions to securely upload recordings to confirm the fidelity of Zoom-based audio transcriptions.

### *Baselines and study schedule*

The study phases are illustrated in Figure 1. A two-week Baseline phase followed the initial Pre assessment, during which subsets of the Spanish and English generalization probes were administered. The subset probes were individualized to sample singleton consonants and clusters that were measured at 0% accuracy during the Pre assessment. This served to establish the stability of consonants and clusters to be monitored for across-language change during and after treatment. The intervention spanned 18 sessions across two phases. Spanish and English generalization probes were administered prior to Treatment Phase 1, before Treatment Phase 2, immediately Post, and at the 2-Week and 2-Month Follow-up appointments. Families were not given any explicit instructions to practise at home during the intervention or the post-intervention period.

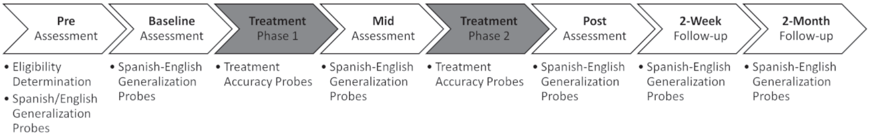

**Figure 1.** Study phases.

### *Assessment*

Prior to treatment, participants completed three assessment sessions during the Pre phase, including comprehensive phonology probes in Spanish and English. The Evaluación de la Fonología Española (EFE; Barlow & Combiths, 2019) is a single-word elicitation probe sampling 255 Spanish words. The Shorter Protocol for the Evaluation of English Phonotactics (Little PEEP; Barlow, 2012) is a single-word elicitation probe sampling 284 English words. Together, these probes provided a minimum of three production opportunities for every consonant and vowel phoneme in each permissible word position and all syllable-initial consonant clusters, in Spanish and English. Word lists for both probes are provided as supplemental files. Both probes were administered in multiple alternating forms prior to treatment, during baseline sessions, and during and post treatment. Productions from these probes provided the data for phonological analysis and cross-linguistic measurement of the effect of treatment. To examine their receptive and expressive language skills, both participants completed the Preschool Language Scales-Spanish, Fifth Edition (PLS-5 Spanish; Zimmerman et al., 2012). Expressive and receptive communication scores were within the typical range for both children.

### *Outcome measurement*

Consistent with prior research measuring broad phonological growth in treatment for PD in Spanish (Anderson, 2002; Barlow, 2005; Combiths et al., 2022a) and English (Combiths et al., 2019; Gierut & Champion, 2001; Potapova et al., 2022), across-class phonological change was monitored via the subset of consonants and consonant clusters produced with 0% accuracy during the pre-intervention assessment and across all baseline sessions (hereafter referred to as monitored sounds). This provides a measure that can be linked to a treatment effect above and beyond the ever-present forces of maturation, time, and spontaneity within a dynamic developing system (Thelen, 2005). Thus, this study operationalized cross-linguistic generalization as change in accuracy of monitored sounds (singleton consonants and consonant clusters) in English and Spanish over the course of treatment, as contrasted to these measurements across the baseline period.

## ***Treatment targets***

The purpose of this study was to examine cross-linguistic generalization effects following treatment of a complex consonant cluster in Spanish. Consequently, all Spanish consonant clusters produced with 0% accuracy across Pre and Baseline assessments were potential targets. Lydia's target was /gɾ-/, selected for her 0% accuracy with this cluster and low accuracy with its constituent phonemes /g/ and /ɾ/. For the same reasons, Julia's target was /kɾ-/. Each participant had a set of six treatment words containing their target cluster in word-initial position. Treatment words were disyllabic real and non-words selected following Combiths et al. (2022a) to include the same distribution of word types (i.e. each participant had two animate nouns, four inanimate nouns, and one verb) and a variety of vowel nuclei in the initial syllable. Each set included three real words: *grano* 'grain', *grillo* 'cricket', *grupo* 'group' and *craneo* 'head', *cresta* 'crest', *crepa* 'crepe' and three non-words: *groki*, *gruka*, *grema* and *croki*, *cruka*, *crima*. Singleton /k/ occurred in two of the participants' treatment non-words, in a non-targeted position, which constitutes additional production of velar stops that were components of the participants' target clusters. However, feedback was provided for production of the target cluster only, and production accuracy during treatment probes was based only on productions of the word-initial cluster. Non-words were included in these sets to maximize the likelihood of mastery of the target structure and generalization to untreated contexts (Cummings et al., 2019; Cummings & Barlow, 2011; Gierut et al., 2010; Gierut & Morrisette, 2010).

### Intervention procedures

Treatment followed procedures described in Combiths et al. (2022a) for treatment of complex Spanish phonology, with adaptations made to activities to suit the virtual modality. Treatment consisted of three one-to-one teletherapy sessions per week, for six weeks, with each session lasting approximately 40 minutes. Treatment occurred in two phases. Phase 1 used imitation as the primary elicitation strategy. In this phase, the clinician's goal was to maximize modelling of correct production, eliciting at least 100 production attempts in imitation and providing immediate feedback on performance or accuracy (see Baker et al., 2018). Phase 2 prioritized spontaneous production. In this phase, the clinician continued to elicit at least 100 production attempts; however, elicitation activities provided opportunities for spontaneous production without the clinician's model. Activities were also expanded to elicit productions of target words in varied contexts (i.e. phrases, conversations, and stories). Feedback on performance or accuracy continued to be given; however, it was reduced in frequency and periodically delayed to provide opportunities for self-monitoring (Shriberg & Kwiatkowski, 1990). To maintain engagement via teletherapy, activities made use of colourful displays, including movement and animations and incorporated characters and motivators based around each child's interests.

### Transcription and analysis

Spanish–English generalization probe administrations via Zoom were recorded and transcribed by the first and second authors. Participants' productions of elicited words were transcribed using narrow phonetic notation with the International Phonetic Alphabet from Zoom audio and video recordings in Phon (Rose & Hedlund, 2021). Productions deemed indistinguishable due to latency issues or microphone placement were omitted from analysis. Inter-rater transcription reliability (e.g. Shriberg & Lof, 1991) was calculated for 20% of the Pre and Post assessment probes by a research assistant with no knowledge of the participant, session number, or treatment phase of the samples at 90.5% in Spanish and 92.1% in English. Accuracy of each English and Spanish singleton consonant and word-initial consonant cluster was generated with a Python script that aggregated Phon accuracy query output, available at https://github.com/philcombiths/Phon_phone_accuracy. From these, accuracy of monitored sounds was derived for each language. To derive clinical effect size, Percentage of Consonants Correct-Revised (PCC-R; Shriberg et al., 1997; Shriberg & Kwiatkowski, 1982b) was generated with the percent phones correct analysis in Phon, occurrence of phonological processes was calculated using PhonoErrorPatterns, a Python script using PanPhon (Mortensen et al., 2016), available at https://github.com/philcombiths/PhonoErrorPatterns, and SMD (Gierut et al., 2015; Gierut & Morrisette, 2011) was calculated for each language as follows:

$$\textit{standard mean difference (SMD)} = \frac{(\text{Accuracy}_{\textit{Pre+Baselines}} - \text{Accuracy}_{\textit{Mid+Post}})}{\text{SD}_{\textit{Baselines}}}$$

Note that *Accuracy* here refers to composite accuracy of monitored sounds from generalization probes administered at the indicated phases, and *SD* refers to the standard deviation of accuracy of all singleton consonants and clusters identified at 0% accuracy pre-treatment, from generalization probes administered across baselines.

## Results

The results for both participants are described first in terms of each child's change in treatment target accuracy on each treatment day. Then results are described for the dependent variables, change in accuracy of monitored sounds (i.e. singleton consonants and clusters at 0% accuracy across baselines), in Spanish and English. This is followed by an analysis of phonological patterns, an estimate of the effect size of intervention, and PCC-R, a typical clinical metric of phonological change. All analyses are provided in the treated language (Spanish) and the non-treated language (English).

### *Treatment target accuracy*

At the beginning of each treatment session, the clinician elicited three productions of each of the participants' six treatment words (18 productions total) using an elicitation probe. Accuracy of the target structure (i.e. /gɾ-/ or /kɾ-/) was assessed using a visual analogue scale (Munson et al., 2012) adapted for consonant clusters (Taps Richard, 2018), with a minimum score of 0 (complete omission of the cluster) and a maximum score of 7 (accurate production of both segments in the cluster) for each production. The scoring system for this scale, with production examples, is provided in Table 2. Scoring was completed by a Spanish–English bilingual research assistant using de-identified audio with no knowledge of the session number or treatment phase of the sample. Accuracy scale ratings during the intervention are provided in Figure 2. Both participants improved accuracy of the targeted cluster over the course of treatment, although neither participant achieved mastery of their target during the six-week intervention period.

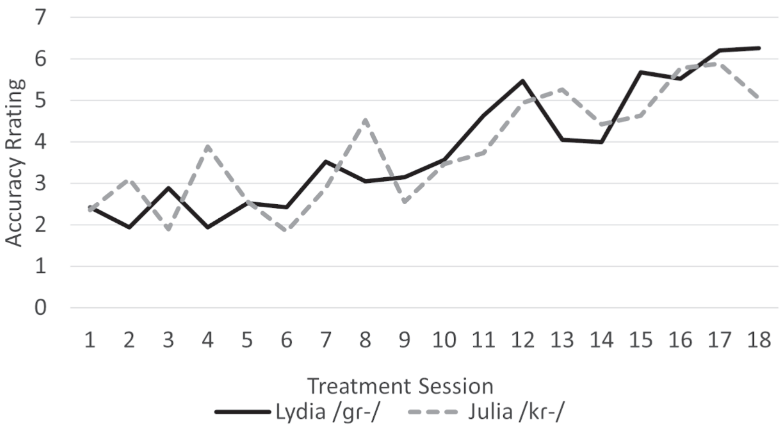

**Figure 2.** Treatment target accuracy during treatment.

**Table 2.** Visual analogue scale description with production examples. n/a indicates a score was not attested.

| **Score** | **Description** | **Example Production** | |
|---|---|---|---|
| | | **Lydia** | **Julia** |
| **0** | omission | n/a | n/a |
| **1** | one non-target phoneme | [j̢] | [g] |
| **2** | one target phoneme | [g] | [ɾ] |
| **3** | two non-target phonemes | [ij̢] | [tj̢] |
| **4** | one target phoneme + one non-target substitution | [gj̢] | [kj̢] |
| **5** | two near-target approximations or distortions | n/a | n/a |
| **6** | one target phoneme + one approximation or distortion | [gij̢] | [kw] |
| **7** | two target phonemes | [gɾ] | [kɾ] |

## *Generalization to monitored sounds*

The dependent variables are the accuracies of monitored sound structures (i.e. singleton consonants and consonant clusters stable at 0% accuracy across baselines) in Spanish (i.e. within-language growth) and English (i.e. across-language growth). These measures constitute an operationalization of generalized phonological growth within and across languages that is most attributable to the applied intervention.

Composite accuracy for each participant across study phases, in each language, is shown in Figure 3. Each participant's set of monitored sound structures is displayed in Table 3, with accuracy values by study phase. More structures were stable at 0% accuracy in Spanish than in English for both participants. Although both participants had four (Lydia) or five (Julia) English

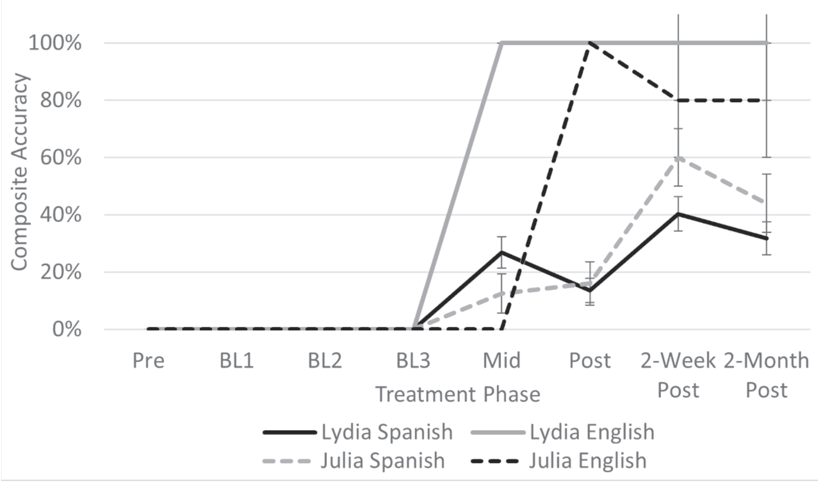

**Figure 3.** Composite accuracy of monitored sounds.

**Table 3.** Accuracy of monitored sound structures by participant and study phase. Values are displayed as proportions. Standard error is in parentheses. Language of monitored sounds are in brackets.

| | | **Lydia** | | | |
|---|---|---|---|---|---|
| **Monitored Sound** | **Pre & BLs** | **Mid** | **Post** | **2-Week Post** | **2-Month Post** |
| /bl-/ [Spa] | 0 (0) | 0.5 (0.29) | 0.25 (0.25) | 0 (0) | 0.75 (0.25) |
| /br-/ [Spa] | 0 (0) | 0.29 (0.18) | 0 (0) | 0.43 (0.2) | 0.14 (0.14) |
| /dr-/ [Spa] | 0 (0) | 0.33 (0.33) | 0 (0) | 0.33 (0.33) | 0 (0) |
| /fr-/ [Spa] | 0 (0) | 0 (0) | 0.25 (0.25) | 0 (0) | 0.25 (0.25) |
| /gr-/ [Spa] | 0 (0) | 0 (0) | 0 (0) | 0.4 (0.24) | 0 (0) |
| /kl-/ [Spa] | 0 (0) | 0.8 (0.2) | 0.8 (0.2) | 0.8 (0.2) | 1 (0) |
| /kr-/ [Spa] | 0 (0) | 0.25 (0.25) | 0 (0) | 0.5 (0.29) | 0 (0) |
| /lj-/ [Spa] | 0 (0) | 0.67 (0.33) | 0.67 (0.33) | 0.67 (0.33) | 1 (0) |
| /pl-/ [Spa] | 0 (0) | 0.33 (0.33) | 0.33 (0.33) | 1 (0) | 1 (0) |
| /pr-/ [Spa] | 0 (0) | 0 (0) | 0 (0) | 0.33 (0.33) | 0 (0) |
| /r-/ [Spa] | 0 (0) | 0.25 (0.11) | 0 (0) | 0.31 (0.12) | 0.13 (0.09) |
| /rj-/ [Spa] | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| /rw-/ [Spa] | 0 (0) | 0.33 (0.33) | 0 (0) | 0.67 (0.33) | 0.33 (0.33) |
| /tr-/ [Spa] | 0 (0) | 0 (0) | 0 (0) | 0.5 (0.29) | 0.5 (0.29) |
| /fl-/ [Eng] | 0 (0) | 1 (0) | 1 (0) | 1 (0) | 1 (0) |
| | | **Julia** | | | |
| **Monitored Sounds** | **Pre & BLs** | **Pre** | **Post** | **2-Week Post** | **2-Month Post** |
| /kr-/ [Spa] | 0 (0) | 0 (0) | 0.5 (0.29) | 0.75 (0.25) | 1 (0) |
| /r-/ [Spa] | 0 (0) | 0.2 (0.11) | 0.07 (0.07) | 0.6 (0.13) | 0.4 (0.13) |
| /rj-/ [Spa] | 0 (0) | 0 (0) | 0.33 (0.33) | 0 (0) | 0 (0) |
| /rw-/ [Spa] | 0 (0) | 0 (0) | 0 (0) | 1 (0) | 0.33 (0.33) |
| /skw-/ [Eng] | 0 (0) | 0 (0) | 1 (0) | 0.8 (0.2) | 0.8 (0.2) |

clusters measured at 0% accuracy during the Pre assessment, only one English structure remained stable at 0% accuracy across all baseline sessions for each participant, and thus was included in the monitored set. Monitored structures in Spanish included the consonant singleton /r/ and many consonant clusters. Consequently, these composite accuracy measures are more informative of system-wide change for Spanish than for English, given that Lydia and Julia's monitored English accuracy reflects accuracy of one structure (/fl-/ and /skw-/, respectively).

In Spanish, both participants demonstrated growth after three weeks of treatment at the Mid phase. Three weeks later, at the Post phase, their Spanish accuracy converged at 14–16%. At the 2-week follow-up visit, growth continued to 40% accuracy for Lydia and 60% accuracy for Julia. At the 2-month follow-up, some of the cumulative growth at the 2-week visit was maintained. Monitored English accuracy change, although representing only one structure for each participant, was observed. Lydia reached 100% accuracy with /fl-/ at the Mid phase. Julia reached 100% accuracy with /skw-/ at the Post phase.

### *Pattern analysis*

Lydia and Julia's distribution of error patterns for all Spanish and English clusters and singletons at pre, post, and follow-up sessions are displayed in Figures 4 and 5, respectively. Pre-intervention, Lydia presented with the following frequencies of occurrence of phonological patterns in Spanish: 33.9% reduction of onset clusters (e.g. /gɾ/ →[g]), 20.3% epenthesis of onset clusters (e.g. /nw/→[nuw]), 15.3% substitution of one or both segments in onset clusters (e.g. /pɾ/→[pw]), 19.3% singleton consonant substitution (e.g. /ɾ/→/n/), and 4.5% singleton consonant deletion (e.g. /l/→Ø). In English, Lydia presented with: 8.6% reduction of onset clusters (e.g. /sk/→[k]), one occurrence of epenthesis (/sl/→[sᵊw]), and 26.5% substitution of one or more cluster segments (e.g., /dɹ/→[dw], 8.3% singleton consonant substitution (e.g. /z/→[ʔ]), and 2.9% singleton consonant deletion – primarily in coda position (e.g., /v/→Ø).

Julia at pre-intervention presented with the following frequencies of patterns in Spanish: 21.0% reduction of onset clusters (e.g. /ɟw/→[w]), 10.1% epenthesis (e.g. /sw/→[suw/), 36.1% substitution of one or both cluster segments (e.g., /kl/→[tjˡ]), 24.7% singleton consonant substitution (e.g., /ɾ/→[d]), and 3.9% singleton consonant deletion (e.g., /f/→Ø). In English, Julia presented with: 8.4% cluster reduction (e.g. /st/→[s]), 5.3% cluster epenthesis (e.g. /spl/→[ spᵊl]), and 30.53% substitution of one or more cluster segments (e.g. /kɹ/→[tɹ]), 20.1% singleton consonant substitution (e.g. /θ/→[f]), and 0.8% singleton consonant deletion – always in coda position (e.g., /l/→Ø).

As shown in Figures 4 and 5, Lydia and Julia substantially reduced the occurrence of phonological processes affecting clusters and singletons, in

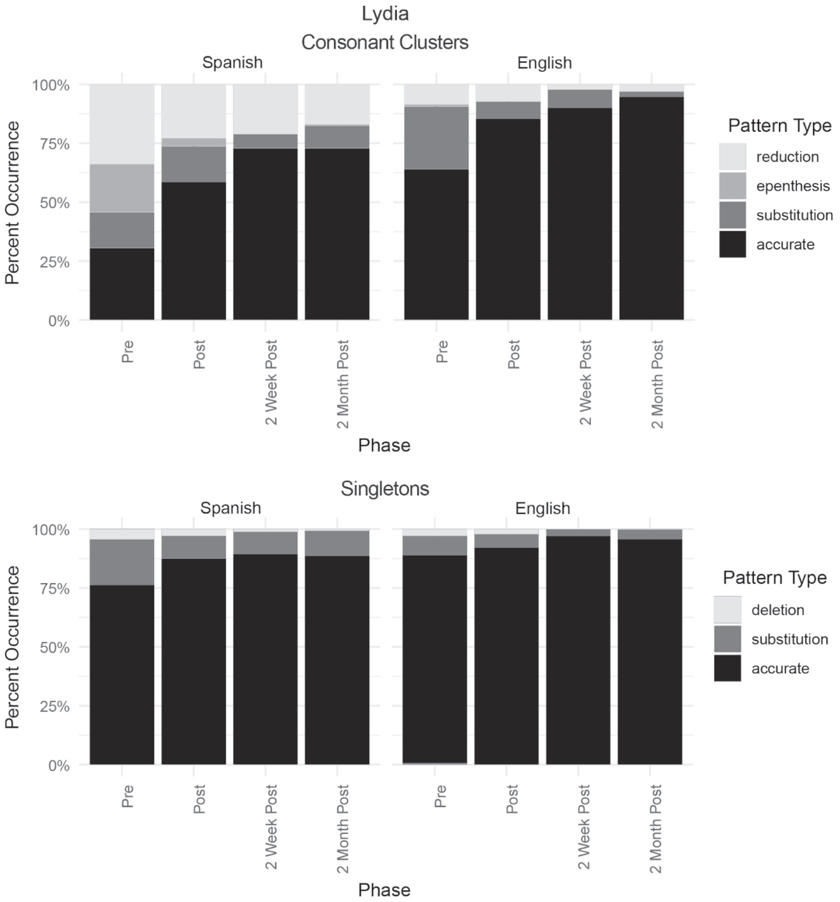

**Figure 4.** Lydia's phonological patterns in English and Spanish.

both languages, following intervention. Notably, the occurrence of patterns that simplify onset clusters to singleton consonants (i.e. cluster reduction and epenthesis) was especially reduced.

### *Effect size and PCC-R*

To provide an estimate of the effect of treatment on monitored sound structures in English and Spanish for each participant, SMD was derived from mean accuracy of 0%-across-baseline monitored sounds prior to treatment and during/immediately following treatment (see Table 4). The difference of these values was divided by the baseline standard deviation of accuracy of sounds identified at 0% accuracy during the Pre assessment, pooled across participants for each language. These procedures follow those used in Combiths et al.

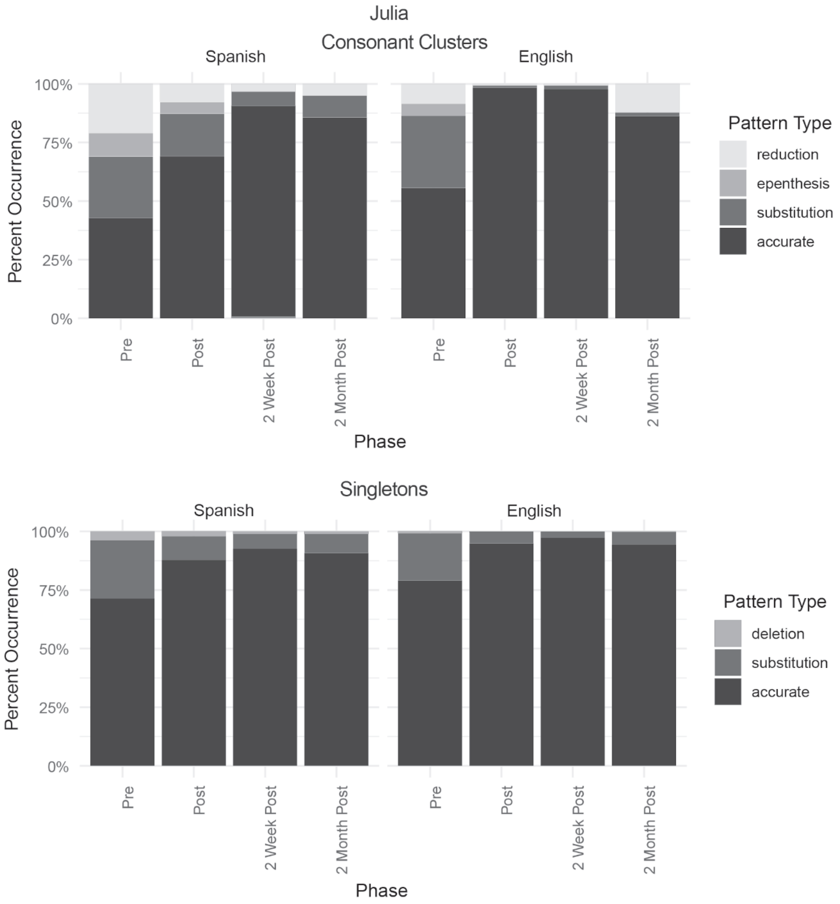

**Figure 5.** Julia's phonological patterns in English and Spanish.

(2022a) for Spanish and are based on those described in Gierut and Morrisette (2011) and Gierut et al. (2015) for English. Per effect size estimates based on English treatment for 135 children with speech sound disorders (Gierut et al., 2015), both participants demonstrated treatment effects, in both treated and non-treated languages, within the medium range (i.e. 2.35–5.89; $M = 3.61$). Notably, effect sizes were similar across languages for each participant, despite treatment occurring only in Spanish.

To describe cross-linguistic outcomes via a typical clinical metric, PCC-R was calculated for each administration of the Little PEEP and EFE generalization probes across study phases (see Table 5). Change from Pre to Post phases are given in Table 6. Unlike the monitored sounds, which were selected for their stable 0% accuracy, PCC-R values reflect accuracy across all consonants,

**Table 4.** SMD effect sizes. $SD_{pooled}$ = denominator of SMD calculation. $M_{BLs} - M_{Tx}$ numerator of SMD calculation.

| Name | Language | $SD_{pooled}$ | $M_{BLs} - M_{Tx}$ | SMD effect size |
|---|---|---|---|---|
| Lydia | Spanish | 0.05 | 0.20 | 4.19 |
| | English | 0.18 | 1.00 | 5.69 |
| Julia | Spanish | 0.05 | 0.14 | 2.95 |
| | English | 0.18 | 0.50 | 2.84 |

**Table 5.** PCC-R by participant, language and study phase. Standard error is in parentheses.

| Child | Language | Pre | Mid | Post | 2-Week Follow-up | 2 Month Follow-up |
|---|---|---|---|---|---|---|
| Lydia | Spanish | 73.4% (1.5%) | 86.9% (1.2%) | 84.1% (1.3%) | 87.9% (1.1%) | 87.5% (1.2%) |
| | English | 87.2% (1.1%) | 92.1% (1.0%) | 92.1% (0.9%) | 95.7% (0.6%) | 95.9% (0.6%) |
| Julia | Spanish | 69.9% (1.6%) | 80.2% (1.4%) | 85.3% (1.2%) | 93.2% (0.9%) | 90.4% (1.0%) |
| | English | 78.7% (1.3%) | 91.7% (0.9%) | 95.6% (0.7%) | 97.7% (0.5%) | 94.3% (0.7%) |

**Table 6.** Pre to Post change in PCC-R by participant and language.

| Participant | Language | Δ PCC-R Pre–Post |
|---|---|---|
| Lydia | Spanish | 10.7% |
| | English | 4.9% |
| Julia | Spanish | 15.3% |
| | English | 16.9% |

in all word positions, regardless of context. Growth was also documented with this clinical measure in both the treated language (Spanish) and the non-treated language (English). Of note, PCC-R was higher in English than in Spanish at the study onset for both participants, and differences between SMD effect size and PCC-R across participants suggest that Lydia exhibited more growth in the monitored set of sounds (i.e. those at 0% accuracy prior to treatment) and Julia exhibited more growth across all sounds (i.e. both low- and high-accuracy sounds).

## *Summary of individual outcomes*

Over the course of treatment, Lydia's production accuracy for her treatment target, /gɾ-/, improved from 2.4 to 6.3 (on a 7-point scale), and her mean accuracy improvement pre-to-post-treatment, across all the consonants and clusters that remained stable at 0% accuracy during baseline was 14%. Of 14 clusters and consonants in Spanish that were monitored at 0% accuracy prior to treatment, 10 increased in accuracy at the Mid or Post assessments. One English cluster monitored at 0% accuracy prior to treatment reached 100% accuracy at the Mid and Post assessments. These accuracy improvements constituted a medium SMD treatment effect size (Gierut et al., 2015) in Spanish (4.19) and via transfer to the non-treated language, English (5.69). In clinical terms, Lydia's PCC-R increased by 10.7% and 4.9% in Spanish and English, respectively, immediately following treatment.

By the end of treatment Julia's accuracy with her treatment target, /kɾ-/, had increased from 2.4 to 5.1 (on a 7-point scale) with fluctuation across sessions. Of four consonants and clusters in Spanish in her monitored set of 0%-accuracy-at-baseline sounds, three improved at the Mid or Post assessments. One monitored English cluster rose from 0% accuracy to 100% accuracy at the Post assessment. Julia also demonstrated a medium treatment effect size in both languages (2.95 in Spanish; 2.84 in English). Julia's PCC-R, measured across all consonant occurrences, improved by 15.3% and 16.9% in Spanish and English, respectively.

## Discussion

The objectives of these studies were to determine the efficacy of intervention in Spanish targeting consonant clusters via teletherapy and to describe the presence or absence of generalization in the form of system-wide phonological change in Spanish, the language of treatment, and via transfer to English, the non-treated language. Multiple baselines provided a set of stable monitored sounds used to quantify treatment outcomes. Two simultaneous treatment case studies were conducted with Lydia and Julia, two young Spanish–English bilingual children with PD who completed 6 weeks of teletherapy intervention targeting complex clusters (i.e. /gɾ-/ and /kɾ-/) in Spanish. Accuracy of these monitored sounds across study phases provided longitudinal pre-treatment measurements to contrast with measurements collected during and after treatment, which formed the basis for effect size calculations in the treated and non-treated languages (i.e. SMD; Gierut et al., 2015; Gierut & Morrisette, 2011). Additionally, percent occurrence of phonological patterns and PCC-R were calculated as clinically relevant measurements of change.

### *Clinical and theoretical implications*

Clinically, growth across classes was documented following teletherapy targeting complex consonant clusters in Spanish for two Spanish–English bilingual children with PD. This aligns with expectations for treatment using complexity-based target selection procedures, further supporting the conclusion that phonological complexity can drive growth across the phonological system (Maggu et al., 2019, 2021) and that its implementation is feasible in Spanish (Anderson, 2002; Barlow, 2005; Combiths et al., 2022a). Using SMD and PCC-R as metrics for comparison, the average effect size, in Spanish, from this teletherapy intervention targeting consonant clusters was 3.57, and average Spanish PCC-R change was 13.0%. A similar in-person intervention targeting consonant clusters in Spanish resulted in an average SMD of 5.0 and average Spanish PCC-R change of 6.8% (Combiths et al., 2022a). Broad growth was documented in both treatment modalities, supporting the efficacy of teletherapy intervention targeting consonant clusters in Spanish for children with PD.

The nature of generalization within a complexity approach is expected to follow implicational relationships based on markedness (Gierut, 2007). It is thus appropriate to further consider the outcomes of this study in the context of markedness-based predictions. Lydia's target was the cluster /ɡɾ-/. In Spanish, voiced stops /b, d, ɡ/ are often described as such because they are produced as stops in certain fortifying phonetic environments, but are produced as approximants in all other contexts and can thus be considered approximants (i.e. /β̞, ð̞, ɣ̞/) underlyingly (Baković, 1994; Barlow, 2003; Fabiano-Smith et al., 2015). Phonologically, approximant + liquid clusters, like /ɡɾ-/, are relatively marked, and typically developing Spanish–English bilingual preschool children produce these clusters with lower accuracy than many other cluster types (Lleó & Rakow, 2005). Across English and Spanish, Lydia produced nine monitored consonant clusters and one singleton consonant with improved accuracy either mid- or immediately post-intervention (see Table 3). Of these, Spanish /bl-, kl-, lj-, pl-/ and English /fl-/ demonstrated sustained change across mid- and post-intervention timepoints. This could reflect both horizontal generalization of /ɾ/ to the other liquid /l/ in cluster contexts and generalization to simpler cluster structures (i.e. voiceless obstruent clusters /kl-, pl-, fl-/).

Julia's target was /kɾ-/. This voiceless stop + liquid cluster is relatively less marked and less complex than /ɡɾ-/, given that voiceless stops are always produced as stops (i.e. not approximants) in Spanish. Julia produced two Spanish clusters, /kɾ-, rj-/, one Spanish singleton, /r/, and one English cluster /skw-/ with improved accuracy either mid- or immediately post-intervention. Growth in a singleton consonant (i.e. /r/) following treatment with clusters and growth in related structures are predicted forms of generalization (Gierut, 2007). The specific markedness relationship between tap /ɾ/ (included in the treated cluster) and trill /r/ in Spanish is less clear, although trill /r/ is articulatorily complex and typically acquired later than tap /ɾ/ (Jimenez, 1987; Linares, 1981; McLeod & Crowe, 2018).

Prior studies have found that children tend to master simpler targets faster than more complex targets (Dyer et al., 1987; Elbert et al., 1984; Powell et al., 1998; Rudolph & Wendt, 2014; Rvachew & Nowak, 2001; Tyler et al., 1993). This is consistent with the outcomes in the current study. Julia began to generalize her treatment target /kɾ-/ to other unpractised words with /kɾ-/, whereas Lydia, who was treated on the more complex /ɡɾ-/, did not. Finally, when each participant's generalized growth beyond the treated target is viewed via effect size, Lydia demonstrated greater generalized growth than Julia (see Table 3), which is also consistent with the relative markedness of their respective treatment targets, as Lydia's approximant + liquid cluster target is a more marked structure than Julia's stop + liquid cluster target. However, future work will need to confirm how markedness principles and implicational relationships apply to Spanish in a developmental context (see Watts & Rose, 2020).*

Perhaps one of the most interesting questions that arises with speech treatment involving bilingual children is the nature of across-language transfer in a clinical context. In this study, comprehensive phonological probes provided production data in Spanish and English across study phases, with some degree of pre-treatment stability to offer insight into treatment-induced transfer. Previous work has documented direct transfer of improvement to phonological structures across languages when treatment is provided in one language or both languages, especially when those structures are similar or analogous across the two languages (Gildersleeve-Neumann & Goldstein, 2015; Holm et al., 1997; Holm & Dodd, 2001; Nye, 2019; Ramos & Mead, 2014; Ray, 2002; Rossouw & Pascoe, 2018). In the current study, the complexity of targeted speech sounds was expected to facilitate a broader form of phonological growth, following previous work (Anderson, 2002; Barlow, 2005; Combiths et al., 2022a) in Spanish. Notably, this system-wide phonological growth was documented, not only in Spanish, the language of treatment, but also in the non-treated language, English. This finding suggests that the positive effects of cross-linguistic transfer in speech intervention may not be limited to transfer of directly analogous structures. Also notable was the observation that broad improvement in the non-treated language was as substantial as the effect observed in the treated language. In this intervention, the language targeted in treatment was also the participants' native language, and this could have facilitated across-language transfer of the treatment effect (e.g. Kohnert et al., 2005; Pham et al., 2015).

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*Watts and Rose (2020) examined how predictions based on implicational markedness relationships compare to cross-linguistic developmental phonological data. Some but not all markedness relationships were attested in developmental data when they included languages other than English. This suggests that nuance is necessary when applying markedness to developmental data.

Finally, these results can be interpreted in consideration of the interconnectivity across bilingual children's two language systems and the mechanism driving broad growth with treatment targeting complex phonology. The theoretical underpinnings of complexity-based target selection relate to cross-linguistic constraints that restrict some structures in a child's phonological system (Gierut, 2007). Strategic introduction of a complex structure into that system presumably requires the child's system to reorganize itself, including its hierarchy of given constraints. At least within a generativist phonological framework, these principles and constraints are thought to be language-universal aspects of the phonological grammar that are implemented in language-specific ways (Chomsky & Halle, 1968; Prince & Smolensky, 1993). If the broad changes often observed with a complexity-based approach are transferrable across languages, this could relate to the language-general influence of complexity on the language learning apparatus or the interconnectivity of distinct phonological systems, as in the revised PRIMIR model of bilingual phonological acquisition (Curtin et al., 2011). In either case, the potential to extend system-wide phonological growth from one language to multiple languages in treatment for bilingual children merits further investigation of this treatment approach for bilingual children.

### *Limitations and future directions*

The findings reported herein must be interpreted in the context of this exploratory study design. Having an outcome measure with documented stability across multiple pre-treatment baselines provides multiple measurements against which the observed change during and after treatment can be compared. Further, similarities in the intervention protocol and study design across participants permit a limited degree of comparison and generalization across them. However, the data are insufficient for generalization to the greater population of Spanish–English bilingual children with PD. First, the variability among bilingual children across factors known to impact response to treatment and across-language transfer is too great (Hambly et al., 2013) to assume homogeneity sufficient for generalization of these findings. Second, the set of monitored sounds in English was limited to one structure for both participants, such that treatment-induced change in English is most appropriately anchored to those specific structures. This sampling limitation is accounted for, at least to some extent, in the SMD effect size measure, reduction of phonological error patterns, and PCC-R during and after treatment, which each suggest that widespread growth in English did occur.

The outcome of this study is broadly consistent with markedness-based relationships that predict a system with a more established representation of complex clusters is also more likely to develop related structures and implied, simpler clusters and singletons. However, we highlight that other developmental frameworks, such as language learnability and dynamic systems theories also predict that complex or novel input to a child's sound system can trigger change in a phonological system in more general or less predictable ways (Rvachew & Bernhardt, 2010; Tesar & Smolensky, 2000). There are also likely to exist other factors introduced into treatment when targeting a relatively complex structure that could impact the amount of growth observed. For instance, teaching a more complex structure may constitute a more difficult task for the clinician or the child, resulting in qualitative or quantitative differences in cognitive recruitment or even tangible differences in the teaching or learning approaches used. Future research could benefit from disentangling predictable linguistic influences from less predictable developmental variability.

To conclude, this initial study supports the efficacy of teletherapy intervention targeting consonant clusters in Spanish for Spanish–English bilingual children with PD. Although these results are not yet generalizable, they indicate that the potential for broad cross-linguistic growth following treatment targeting a complex phonological structure is a viable avenue for continued research. Indeed, continued investigation into system-wide transfer of intervention effects could improve speech-language pathologists' ability to provide optimal intervention for bilingual children with speech sound disorders.

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