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Research Article

Contributions to Gain in Speech Sound Production Accuracy for Children With Speech Sound Disorders: Exploring Child and Therapy Factors

Kelly Farquharson,[a] Sherine R. Tambyraja,[b] and Laura M. Justice[b]

Purpose: The purpose of this study was to explore the extent to which child- and therapy-level factors contribute to gains in speech sound production accuracy for children with speech sound disorders in receipt of school-based services.
Method: Data were obtained from 126 kindergarten and first- and second-grade children currently in receipt of speech therapy services in their public school setting. Pretest and posttest measures of spontaneous speech production and language ability were collected at the beginning and end of one academic year. Using a spontaneous speech sample, percentage of consonants correct (PCC) was calculated for each child; a gain score was computed by subtracting the pretest PCC score from the posttest PCC score. The children's speech-language pathologist completed weekly therapy logs during business-as-usual therapy, indicating the frequency, duration, and group composition of services throughout the school year.
Results: Results supported that gain in PCC from pretest to posttest was predicted by several child- and therapy-level variables. Children's initial speech sound severity was negatively related to gains in PCC. Our results also supported that the total number of therapy sessions received in a year was positively predictive of PCC gain. Interestingly, the number of individual therapy sessions was negatively associated with PCC gain.
Conclusion: Several malleable therapy factors contribute to gains in speech sound accuracy for children with speech sound disorders. Speech-language pathologists should consider how these factors may be manipulated to best tailor treatment to the individual needs of the children on their caseloads.

Over 90% of school-based speech-language pathologists (SLPs) report working with children with speech sound disorders (SSDs; American Speech-Language-Hearing Association [ASHA], 2018a). Children with SSDs have steadily comprised 36%–46% of SLPs' caseloads over the past decade (ASHA, 2018b). Despite these relatively high numbers (ASHA, 2018a; Shriberg et al., 1999; Wren, 2015; Wren et al., 2016), there is scarce evidence regarding the extent to which children's speech sound production skills improve from school-based therapy and the malleable treatment-level factors that contribute to that improvement. Indeed, previous reports from observational as well as researcher-controlled intervention studies indicate that child-level factors, such as the type of speech error (Preston et al., 2013), age, error consistency, and expressive morphology (Tyler et al., 2003), are associated with children's gains in speech sound production.

However, and quite surprisingly, there is a dearth of evidence examining the extent to which structural aspects of school-based therapy services, such session length, frequency, and group composition, contribute to gains in speech sound production (see Justice, 2018, for review). For instance, in a review of 134 different treatment studies, Baker and McLeod (2011) found substantial variability for session length, which ranged from 15 to 270 min. The majority of studies reported 30- to 60-min sessions. Additionally, session frequency ranged across treatment studies from once per month to five times per week; the majority of studies implemented two sessions per week. Several additional systematic reviews have reported on the issue of treatment intensity for children with SSDs (e.g., Kaipa &

[a]School of Communication Sciences and Disorders, Florida State University, Tallahassee
[b]Crane Center for Early Childhood Research and Policy, The Ohio State University, Columbus
Correspondence to Kelly Farquharson: kyfarq@gmail.com

Editor-in-Chief: Holly L. Storkel
Editor: Marleen F. Westerveld
Received October 2, 2019
Revision received November 26, 2019
Accepted December 4, 2019
https://doi.org/10.1044/2019_LSHSS-19-00079

Disclosure: *The authors have declared that no competing interests existed at the time of publication.*

Peterson, 2016; Sugden et al., 2018). However, there are only a few treatment studies available that have empirically tested how much intervention is necessary to make the desired change (e.g., Allen, 2013; Hitchcock et al., 2019; Page et al., 1994; Skelton & Richard, 2016; Williams, 2012). Even fewer studies examine how much intervention is necessary to make changes within school-based settings, where many SLPs experience time and caseload constraints (e.g., Biancone et al., 2014). As such, the purpose of this study is to explore both the child-level and the therapy-level factors that may contribute to gain in speech sound accuracy, measured by percentage of consonants correct (PCC), for school-aged children with SSDs receiving services in U.S. public school settings.

Using PCC to Measure Change in Speech Sound Production

The ultimate goal for all speech therapy sessions, regardless of behavior of interest, is to invoke change. Frequently, this change is conceptualized in terms of skills gained, but the goal may also be to reduce the incidence of a behavior. For children with SSDs, the goal of therapy is to increase the correct use of speech sounds during spontaneous speech. The ways in which this is measured may vary, but PCC (Shriberg et al., 1997) is a common metric. PCC is calculated by counting the total number of consonants available in a spontaneous speech sample (denominator) and then determining the total number of those consonants that a target child produced correctly (numerator). Dividing the numerator by the denominator and multiplying by 100 results in a percentage that can quantify the severity of a child's SSD.

Note that there have been several adaptations of PCC (e.g., Campbell et al., 2007). In an adjusted version of the PCC metric (Shriberg et al., 1997), common clinical distortions are not counted as speech sound errors. Common clinical distortions (Shriberg, 1993) include distortions of /l, r, s, z, ʃ, ʒ, tʃ, dʒ/. It can be problematic to exclude these common clinical distortions because they occur frequently among school-aged children with SSD and often are the basis of their qualification for services (Farquharson, 2019; Farquharson et al., 2018; Preston & Edwards, 2007; Wren, 2015). Furthermore, studies suggest that children exhibiting these speech distortions may still experience difficulties with literacy and/or social–emotional well-being (Farquharson, 2019; Hitchcock et al., 2015; Krueger, 2019). Specifically, there is an educational impact as a result of isolated SSDs (Farquharson & Boldini, 2018), including difficulties with phonological working memory (Cabbage et al., 2015; Farquharson et al., 2018), decoding (Cabbage et al., 2018), and spelling (Apel & Lawrence, 2011; Farquharson, 2019; Lewis et al., 2018). It is certainly true that children with SSDs in isolation may experience persistent SSDs, regardless of language ability (Farquharson, 2015; Preston & Edwards, 2007; Raitano et al., 2004). In this study, we explore the factors that contribute to change in speech sound abilities in school-aged children with SSDs by calculating their PCC in a narrative retell at the beginning and end of one academic year.

Child-Level Factors as Predictors of Change in Speech Sound Production

Child-level factors have previously been shown to relate to gains in speech sound production over time. For instance, Tyler et al. (2003) explored several factors that may contribute to change in PCC following a 24-week intervention period in preschool children with SSD and comorbid Language Impairment. These researchers found that the consistency of the speech sound error and a measure of expressive morphology explained more than half of the variance of gain in PCC. In a replication study reported by the same researchers, only error consistency was associated with gains in PCC. Note, however, that in both the initial and the replication study, error consistency accounted for nearly the exact same percentage of the variance (i.e., 31%) in change in PCC from the beginning to the end of treatment. Thus, the relationships between language ability and PCC gain remain unclear. Still, many children with persistent SSD exhibit concomitant language difficulties as well (Lewis et al., 2000; Sices et al., 2007). The prevalence of children with SSDs and children with language impairments on the caseloads of school-based SLPs (ASHA, 2018a), paired with the overlap of these two disorders (e.g., Lewis et al., 2000), make it crucial that we understand how language ability influences gains in speech sound production accuracy.

In addition to language ability, the severity of children's speech sound errors will likely contribute to how much they progress over time. Although previous studies have controlled for initial PCC when evaluating gains over time (e.g., Allen, 2013), the directionality of the potential associations between initial severity and subsequent gains are unclear. For instance, it is plausible that children with more severe speech sound errors will demonstrate slower rates of gain over time, as they have more errors to be corrected, and/ or more atypical errors that require intense intervention. However, it could also be the case that children with more severe speech sound errors will demonstrate larger gains, as they simply have more room for change, as a result of therapy. In either situation, understanding the extent to which SSD severity impacts gains over time is particularly informative for school-based SLPs, who serve children demonstrating a range of speech sound production skills.

Therapy Factors That May Predict Change in Speech Sound Production Accuracy

Although there are many speech sound intervention studies available, few examine the influence of business-as-usual therapy for school-aged children in receipt of school-based therapy in U.S. public schools on children's

speech sound outcomes. This setting is a unique and important one to examine because nearly 90% of U.S. school-based SLPs report working with children with SSDs (ASHA, 2018a), and SSDs often impact educational performance (Farquharson & Boldini, 2018; Overby et al., 2012). Previous reports have investigated business-as-usual therapy in the schools with respect to quality of language intervention (Biancone et al., 2014), composition and location of language intervention (Farquharson et al., 2015; Tambyraja et al., 2014; Tambyraja, Schmitt, et al., 2015), and classroom quality for children with language impairments (Tambyraja, Farquharson, et al., 2015). Similar to children with language impairments, children with SSDs are continually among the top three populations of children reported to be receiving services in schools over the past 10 years (ASHA, 2018b). However, we know very little about the ways in which children with SSDs receive and are receptive to school-based therapy.

There are numerous intervention parameters that contribute to gains in children's speech sound skills, such as treatment approaches, techniques, frequency, and duration (see Baker & McLeod, 2011; Justice, 2018). This sought to determine the extent to which service provision factors of school-based therapy related to gains in children's PCC over the course of an academic year, as these variables must be considered across school-based settings. Moreover, these characteristics, including time in therapy and therapy group size, are potentially malleable factors that SLPs may be able to adjust and amend accordingly. Specifically, if our results support that therapy-level characteristics such as time in therapy and therapy group size influence outcomes for children with SSDs, then SLPs may be able to tailor their service provision in ways that lead to more effective treatment for children with SSDs. This study aims to provide an in-depth examination of the extent to which the frequency, duration, and group composition of therapy contribute to gains for children with SSDs.

Session Frequency

Session frequency refers to the number of times a child is seen in a particular week. In the extant literature, frequency ranges across treatment studies from once per month to five times per week; the majority of studies implement two sessions per week (Baker & McLeod, 2011). In school-based settings, SLPs report that severity of the disorder drives session frequency, indicating that children with more severe communication impairments receive intervention two to three times per week for 20- to 30-min sessions (Brandel & Loeb, 2011; Mann Brumbaugh & Smit, 2013); children with less severe impairments receive intervention one time per week for 20–30 min. In the most recent ASHA Schools Survey (ASHA, 2018a), respondents indicated that, on average, the majority of the children on their caseload—regardless of diagnoses—receive up to 1 hr of therapy per week. Only 12% of respondents indicated that children on their caseload receive more than 1 hr of therapy per week. International reports of treatment frequency are similar but include sessions as frequent as five times per week (Ruggero et al., 2012). Distributed practice theory suggests that purposefully spacing stimuli within treatment results in better acquisition and retention (e.g., Cepeda et al., 2006). However, the extent to which session frequency is associated with change in speech sound production in the course of an academic year remains critically understudied.

Session Duration

Session duration refers to the length, typically measured in minutes, of individual sessions. Broadly, studies describing therapy for children with SSDs report substantial variability for duration, ranging from 15 to 270 min. The most recent systematic review of speech sound interventions found that the session duration most commonly used in research studies was either 30- or 60-min sessions (Baker & McLeod, 2011). These data align with survey-based studies, indicating that most school-based SLPs design 30-min therapy sessions (Brandel & Loeb, 2011; Mann Brumbaugh & Smit, 2013; Schmitt et al., 2017). Additionally, Mullen and Schooling (2010) reported on ASHA National Outcome Measurement System (NOMS) data. Their reports of service delivery indicate that 21- to 30-min sessions are the most common in school-based settings, with fewer than 7% of students receiving SLP services for longer than that. To date, we know of no studies that provide an evidence base for school-based SLPs to make important clinical decisions regarding appropriate session duration.

Therapy Group Format

In addition to examining therapy frequency and duration as they relate to children's gains in speech sound production, a related and similarly understudied issue pertains to the relative efficacy of providing services to children with SSDs in small groups outside of the classroom. Small group therapy is the most frequent option used by school-based SLPs (Brandel & Loeb, 2011; Mann Brumbaugh & Smit, 2013) as compared to individual treatment sessions (Baker, 2012; Baker & McLeod, 2011; Williams, 2012), which is the service delivery model most frequently used in research studies. This is an important element of therapy that must be further investigated, particularly because "incorporating optimal service delivery models" is listed as one of the greatest challenges faced by school-based SLPs (ASHA, 2018a). Reports of ASHA NOMS data indicate that nearly 82% of children working on speech sound production in K-12 U.S. schools most frequently receive services in a group of two to four students outside of the general education classroom; fewer than 10% of students receive individual therapy (Mullen & Schooling, 2010). Cirrin et al. (2010) conducted a systematic review of the literature to determine the influence of school-based service delivery models (direct vs. indirect, group vs. individual, pull-out or push-in, etc.) on a variety of speech and language outcomes for school-aged children. In their review of 255 articles, there were only five available studies that empirically tested

the impact of service delivery models on child outcomes. Only two of the five studies reported on the differences between group and individual therapy sessions, with no statistically significant difference between the two. Collectively, it is problematic that the field of speech-language pathology has such scarce evidence to support frequency, duration, and group composition–related decisions to help clinicians determine how much therapy might result in the greatest amount of sustainable gains in the least amount of time.

The current study makes a significant contribution to the body of research aimed at understanding factors that contribute to gains in speech sound production abilities for children with SSDs, with a particular focus on business-as-usual services in the schools. Specifically, the present work sought to answer the following research questions: (a) To what extent do children who receive therapy for speech sound production demonstrate gains in PCC over the academic year? (b) To what extent do child-level and therapy-level characteristics, specific to aspects of frequency, duration, and group composition, contribute to their gains in PCC?

Method

Participants

All aspects of this study were approved by the Institutional Review Board at The Ohio State University. Participants in this study included 55 SLPs working in the public schools in Ohio and Tennessee and 126 children on their caseloads who were receiving school-based speech therapy. All participating SLPs were working in rural and urban public school districts and had received their Master's degree; the majority were female (96%). Years of experience ranged from 0 to 36 years, with a mean of 16.51 (SD = 10.84).

The participating SLPs and children were a subset of those from a larger study aimed at describing business-as-usual speech-language therapy (Speech Therapy Experiences in the Public Schools; see Schmitt et al., 2017, for additional study details) and represented those who had been clinically identified by their participating SLP as requiring articulation/speech sound therapy. Eligibility into the larger study required that children (a) were in current receipt of school-based speech-language therapy; (b) were in kindergarten, first grade, or second grade; (c) did not have a severe cognitive impairment that would impact their ability to complete study tasks; and (d) primarily communicated in English. Participating SLPs provided study information to families of children who met the above criteria. Up to five children per SLP were enrolled in the study, following parental consent. The five children were selected based upon the extent to which they met the inclusionary criteria listed above and the provision of parental consent. Note that some SLPs had fewer than five study-enrolled children as a result. Approximately one third of the current sample (n = 39) were receiving treatment that focused solely on speech sound production (SSD only); the remaining 87 children had treatment goals specific to both speech and language (SSD + language impairment). Our sample of 126 included 39 kindergartners, 82 first graders, and five second graders, all of whom met the above criteria and also had pretest and posttest data (fall and spring time points). The majority of children were male (n = 83), and a range of ethnicities were represented, with 55% being Caucasian. Levels of maternal education were used as a proxy for socioeconomic status; 28% of children had mothers with a college degree or higher. Table 1 includes additional descriptive data for predictor variables. For information about the complete sample in the larger study, see Farquharson et al. (2015).

Procedure

Following consent into the study, children were administered a battery of language and literacy assessments (described below). These assessments were administered at the beginning (fall) and the end (spring) of one academic year in individual testing sessions, each within a predetermined 6-week window (i.e., pretest in the fall = September 1 to October 15; posttest in the spring = April 1 to May 15). Each testing session lasted approximately 45 min and was administered by a trained field assessor in a quiet room. Training components for each measure included (a) review of assessment manual and procedures, (b) completion of an online module about the measure and achievement of a score of 100% on a test administration quiz, (c) completion of a mock assessment, and (d) live observation of the assessor's initial test administration by the research project manager.

All participating SLPs were asked to continue business-as-usual therapy provision and maintain weekly therapy logs for each participating child on their caseload for the duration of the school year (e.g., 35 weeks). Information captured in the therapy logs included the number of sessions completed per week, the duration of each child's therapy session, and the group composition of the therapy (i.e., individual or group sessions). The therapy logs were submitted to research staff using self-addressed stamped mailers. In this study, completed therapy log information was submitted for all participating children.

Measures

Three measures were used to address the study's primary research aims: (a) children's language and PCC at the beginning of the academic year, (b) gains in children's PCC throughout the academic year, and (c) information from the therapy logs pertaining to the frequency, duration, and group composition of therapy sessions throughout the academic year.

Pretest Language and PCC

At the beginning of their academic year, children were individually assessed on a battery of language and literacy assessments. Relevant to this study were measures of overall

Table 1. Descriptive data for child-level and therapy-level predictor variables.

Variable	*M*	*SD*	Range
Child-level variables			
Child age (in months)	76.79	8.25	60–96
Pretest language	73.09	17.60	40–115
Pretest PCC	.86	.08	.60–.98
Therapy-level variables			
Total number of therapy sessions	44.73	17.32	4–116
Total number of minutes in therapy	1193.76	451.93	91–2360
Average therapy sessions per week	1.33	0.46	0.46–3.41
Total number of individual therapy sessions	7.86	13.43	0–90

Note. Pretest language is the standard score on the Clinical Evaluation of Language Fundamentals–Fourth Edition. PCC = percentage of consonants correct.

language ability and a connected speech sample obtained from a narrative retell task.

Language. All children were administered the Core Language subtests (Concepts and Following Directions, Word Structure, Recalling Sentences, and Formulated Sentences) of the Clinical Evaluation and Language Fundamentals–Fourth Edition (Semel et al., 2004) as an index of oral language ability. Standard scores from the subtests were calculated and combined to yield a composite score (i.e., Core Language), for which 100 is the mean and 15 is the standard deviation.

PCC. A story retell task, the Narrative Assessment Protocol (Justice et al., 2010), was administered at pretest and posttest as part of the language and literacy battery to obtain a connected speech sample. This measure was administered to all children using the same protocol, regardless of children's language ability. To administer this test, the examiner showed the child the wordless picture book, *Frog, Where Are You?* (Mayer, 1969), while reading an accompanying text for the story. Children were then asked to retell the story they had just heard while looking at the pictures. On average, children's retells were approximately 3 min in length, allowing for an adequate connected speech sample (Heilmann et al., 2008, 2010; Shriberg et al., 1997). All story retell tasks were videotaped for subsequent transcription.

Children's responses were transcribed verbatim when videos were returned to the lab and 10% of videos were double transcribed for reliability purposes. Additionally, an average word count was determined based on 10% of pretest and posttest samples. Pretest samples averaged 229 words, and posttest samples averaged 258 words. Three student research assistants (RAs) were trained to review the videos again and phonetically transcribe children's responses in order to capture all speech sound production errors. The RAs had all completed and passed an undergraduate course in phonetics, and completed a short phonetics quiz as a refresher. The RAs each completed phonetic transcriptions of five practice videos and compared their work to a master set of transcribed videos. Disagreements to the master set were discussed and explained. Next, each RA completed three additional reliability videos and was required to achieve at last 85% agreement to a master set. Two drift checks were performed throughout the transcription process, and 20% of videos were double transcribed; interrater reliability was adequate at 88%. Each child's PCC score was calculated by dividing the number of correct consonants by the total number of consonants and multiplying by 100. This process was done for all children in the sample for both their pretest and posttest narrative samples.

PCC Gain

The outcome variable of interest in this study was change in children's PCC from pretest to posttest of one academic year. To estimate PCC gain, each child's pretest PCC score was subtracted from their posttest PCC score.

Therapy Logs

SLPs were asked to maintain weekly therapy logs throughout the academic year. These logs recorded the start and stop time of each therapy session for the week, as well as other business-as-usual service delivery factors such as the number of other children in each session and the location of therapy (e.g., speech room, classroom). For purposes of this study, we considered information concerning (a) the total number of therapy sessions each child received throughout the year; (b) the total amount of therapy received, in minutes; (c) the average number of sessions per week; and (d) the total number of individual therapy sessions each child received.

Analytic Strategy

Descriptive statistics were used to address the first study aim that focused on examining gains in children's speech sound production over the course of the year. The outcome variable of PCC gain was examined for possible outliers; one child's pretest to posttest PCC scores differed by −16%, which was more than 3 *SD*s from the mean PCC difference score (3.9%); thus, data for this participant were not included in subsequent analyses. Given the nested nature of the data (children nested within SLPs), the second study aim concerning the contributions of child-specific and therapy-specific variables to gains in

PCC was addressed using a hierarchical linear modeling (HLM) framework (Raudenbush & Bryk, 2002). HLM was used to partition the variance into between- and within-SLP components and to account for the fact that some children were treated by the same SLP and may thus have had some shared therapy experiences. Correlations and variance inflation factors for independent variables were estimated and indicated no multicollinearity problems in the data (e.g., variance inflation factors < 3). As a first step, we fit an unconditional model for children's gains in PCC. Next, all variables were entered as fixed effects into the full model predicting PCC gain. Child age, pretest PCC, and children's pretest language scores were included as continuous child-level (Level 1) variables. The total number of weeks in therapy, total number of minutes in therapy, average number of therapy sessions a week, and the total number of individual therapy sessions were included as continuous therapy-level (Level 2) variables.

Results

Descriptive statistics for all variables included in the analyses are shown in Table 1. The first aim of this research was to determine the extent to which children receiving school-based speech therapy demonstrated gains in speech sound production throughout the year. A PCC gain score was calculated by subtracting children's pretest PCC score (M = 85.94%, SD = .08) from their posttest PCC score (M = 89.85%, SD = .06). On average, children's PCC gain throughout the year was 3.91%, though there was considerable variability (SD = 4.75%; range: −7% to 21%). Results from a paired-samples t test indicated that children's pretest to posttest PCC gains were statistically significant, $t(124) = -9.188$, $p < 001$, Cohen's $d = 0.82$. The effect size for this analysis is considered a large effect according to Cohen's (1988) interpretation.

The second aim of this study was to examine the associations between gains in PCC and several child-specific and therapy-specific variables that were hypothesized to contribute to children's improvement in speech production abilities throughout the year. Prior to answering the second research question, we calculated the intracorrelation coefficient on the outcome variable of children's PCC gains over the academic year. Results indicated that the between-SLP variance was somewhat small (5%) and that the majority of variance in PCC gain was between children (95%); however, given the nested structure of the data, the HLM approach was still considered appropriate.

The HLM analyses evaluated the extent to which three child-level predictors (i.e., child's age, language ability, and pretest PCC) and four therapy-level predictors (i.e., total number of weeks in therapy, total number of minutes in therapy, average number of therapy sessions a week, and the total number of individual therapy sessions) were significantly associated with PCC gain. The full model results (see Table 2) showed that neither children's pretest language scores nor their age were significantly associated with their gains in PCC; however, children's pretest PCC scores were significantly, but negatively, related to PCC gains over the year ($p < .001$). Results also indicated that the total number of therapy sessions that children received over the school year was positively associated with their gains in PCC ($p = .006$). The total number of individual therapy sessions that children received was negatively associated with the gains in PCC ($p = .002$). Following this result, a post hoc bivariate correlation was run to examine the extent to which speech sound severity, measured by PCC at the beginning of the school year, was related to receipt of individual therapy sessions. We found no association between severity and receipt of individual therapy sessions ($r = .075$).

Discussion

The purpose of this study was to explore the child-level and therapy-level factors that contribute to gain in PCC for children with SSDs in receipt of school-based services. Our results support three important and clinically relevant findings. First, children with SSDs receiving services in school-based settings make clinically significant gains in PCC from the beginning to the end of an academic year. Second, the child-level variable that explained these gains was SSD severity. Finally, the therapy-level variables that explained these gains included the total number of therapy sessions received in an academic year and the total number of individual therapy sessions. These results and their clinical implications—including directions for new research—will be discussed in turn.

Speech Sound Change in One Academic Year

Results from our first research aim suggest that children with SSDs make significant gains in PCC during business-as-usual speech sound therapy in public schools. Given the substantial number of SLPs who treat SSDs in the schools, this study provides much-needed information regarding the extent to which children receiving school-based therapy demonstrate improvements that can be expected in an academic year. On average, the children in our sample exhibited a 3.91% increase in PCC from the fall to the spring of one academic year. Previous reports (Austin & Shriberg, 1997) indicate that across 3 years of development, typically developing children between the ages of 6;0 (years; months) and 8;11 experience a 4.1% growth in PCC, on average. When examining PCC growth in the same age group (6;0–8;11) of children with a speech delay, Austin and Shriberg (1997) reported a regression of 3.3% during those 3 years. Note, however, that information on therapy provision and language ability is not reported for this sample. By comparison, children in this study exhibited substantial growth throughout the course of one academic year while in receipt of school-based speech therapy. This is further substantiated by a large effect size. Still, this result should be interpreted with caution.

Other studies have also reported quantitative data regarding growth in speech sound production following

Table 2. Child- and therapy-level variables predicting children's gains in PCC.

Variable	Coefficient	*SE*	*df*	*p* value
PCC gain intercept (γ00)	0.3053	0.0481	117	**< .001**
Child-level variables				
Child age in months	0.0006	0.0004	117	.140
Pretest language	0.0003	0.0002	117	.241
Pretest PCC	−0.3814	0.0472	117	**< .001**
Therapy-level variables				
Total number of therapy sessions	0.0015	0.0006	117	**.006**
Total number of minutes in therapy	−3.418	1.701	117	.052
Average therapy sessions per week	−0.0180	0.0112	117	.111
Total number of individual therapy sessions	−0.0010	0.0003	117	**.002**
Random effects		**Variance**		
SLP-level (τ_{00})		.0001		
Child-level (σ^2)		.0024		

Note. Bold values are statistically significant. PCC = percentage of consonants correct; SLP = speech-language pathologist.

treatment. For instance, Gillon (2002) reported a 14% growth in PCC scores from pretest to posttest following a 10-week researcher-designed phonological awareness intervention. This was in comparison to a control group, who exhibited a growth of 6.8% in PCC during the same 10-week period while receiving speech therapy focusing on speech sound production, but not phonological awareness. Additionally, Tyler et al. (2003) reported a fairly wide range of PCC gain scores from 4% to 26% for their preschool sample who received a 24-week, researcher-designed speech sound intervention. Finally, the children receiving 12 weeks of intervention in Dodd et al. (2008) experienced an average PCC gain of 16%, but with substantial variability. All three studies report impressive gains in PCC as a result of a researcher-designed treatment. Importantly, however, across the three studies, PCC was measured based on a single-word elicitation task. In this study, we calculated PCC based on a connected speech sample, elicited through a narrative retell. These disparate approaches to calculating PCC are very likely to engender different results. Therefore, although the PCC gains we report from business-as-usual school-based speech therapy are smaller than those reported in researcher-designed interventions, these data were obtained from a more naturalistic sample. Future similar work should include both a single-word elicitation task and a narrative sample to compare the differences in PCC growth according to collection method.

Based on data reported by Austin and Shriberg (1997), it was not entirely surprising to see that, for some children, there was a regression in PCC skills from the beginning to the end of an academic year. This is also in line with data reported on ASHA NOMS (e.g., Mullen & Schooling, 2010). For example, Mullen and Schooling (2010) reported that from the time that treatment began to the time a child was dismissed from speech sound treatment in U.S. schools, 42.5% of children had moved up several levels in functional progress and 31% had moved up one level. This leaves approximately 26% of children who have made no functional progress between entrance and dismissal from therapy. Note, however, that functional progress was determined via a 7-point subjective rating scale (e.g., Level 1: "Familiar listeners understand a small number of student's isolated words and phrases in educational activities"; Level 6: "The student's connected speech in educational activities is consistently understood by familiar listeners. Unfamiliar listeners consistently understand connected speech when the context is known and are usually able to understand the student's speech without the context"; Mullen & Schooling 2010, p. 60). There is a range of progress levels reported between entrance and dismissal. Thus, the current study builds upon previous reports of functional improvements in the course of a school year and provides quantitative data regarding that growth.

It is important to note that this sample of children would be categorized as ranging mostly from mild to moderate. There were no children in this sample whose PCC fell below 50%, which would be categorized as severe (Shriberg & Kwiatkowski, 1982). Note that many studies of children with SSDs require a PCC of 80% or less, demarcating a moderate impairment (e.g., Anthony et al., 2011; Nathan et al., 2004; Rvachew & Grawburg, 2006). However, and importantly, the current sample is a clinical population selected from the caseloads of currently practicing SLPs in public schools in the United States. Furthermore, the metric used in the current study—PCC—is a functional measure of speech that also, inherently, includes a measure of intelligibility (Tyler et al., 2003). Therefore, these results offer a realistic representation of the variability and level of severity that school-based SLPs will assess and treat throughout the school year.

Child-Level Factors That Contribute to Speech Sound Production Gains

To answer our second research question, we included several child-level variables. The child-level variables that

we included were child age, language ability, and speech sound severity at pretest, as measured by PCC. We found that age and language ability were not significant predictors of gain. First, this means that regardless of age, children were able to improve their speech sound production during business-as-usual school-based therapy. This is particularly important, as some practices indicate that children need to wait until a certain age (e.g., 8 years old; Wren, 2015) to receive a comprehensive evaluation to determine if speech sound treatment services are warranted (Archibald, 2017; Farquharson, 2019; Farquharson & Boldini, 2018). However, our data suggest that this is not the case. Instead, it appears that, at least for children with relatively mild SSDs, treatment can be effective in improving speech sound production as measured by PCC. As such, it is appropriate to provide treatment to children experiencing mild SSD in kindergarten. Second, we found that language ability did not contribute to gains in speech sound production accuracy. This was surprising given the oft reported high correlation between speech and language abilities, particularly for school-aged children. However, this study used an omnibus language measure (i.e., the Clinical Evaluation and Language Fundamentals–Fourth Edition), which may have precluded our ability to examine how specific domains of language impact speech sound production gains. For instance, Tyler et al. (2003) reported that a measure of grammar was positively and significantly associated with PCC gain. Future research should explore language ability using a more fine-grained measure to examine the extent to which specific domains may impact child outcomes. In the meantime, our results indicate that, although language ability is certainly important to consider for treatment purposes, it may not directly affect the kind of progress that a child can make in a different but related skill like speech sound production. Clinically, this information is useful when considering goal writing and treatment planning, as children with varying levels of language ability can equally make progress in speech sound production accuracy.

The only child-level factor that was a significant predictor of PCC gain was speech sound severity. Surprisingly, children with lower PCCs at pretest made greater gains at posttest. There are several plausible explanations for this finding. First, it is possible that, given the age of some of the children in the sample, this was the first time that they had received therapy for speech sound production (e.g., Glogowska et al., 2000). As such, the gains reported for our sample point to a need for ensuring that children in kindergarten and first grade receive school-based services. Second, it is possible that the gains we are reporting here are related to the fact that children with lower PCCs—and therefore more relatively severe SSDs—simply have more room to grow than children with less severe SSDs. Finally, it is possible that provision of speech therapy within an educational context engenders a specific kind of support necessary to experience gains over time. Although previous studies have also controlled for initial PCC while examining PCC gain (e.g., Allen, 2013), the specific nature of that relation was not explored.

Therapy-Level Variables That Contribute to Speech Sound Production Gains

We also included several therapy-level variables regarding frequency and duration. This question is important, but largely exploratory as the requisite frequency and duration in school-based settings is unknown. Related, there are several ways in which these variables may be operationalized or defined on an Individualized Education Program (e.g., minutes per session/week/month; sessions per week/cycle/9 weeks). Typically, SLPs make these decisions and decisions regarding therapy group composition based upon environmental factors (Brandel & Loeb, 2011; Mann Brumbaugh & Smit, 2013) such as caseload size and scheduling constraints. In this study, we examined how the total number of therapy sessions received throughout the year, total number of minutes in therapy, average number of therapy sessions a week, and the total number of individual therapy sessions contributed to children's gains in speech sound production. Results indicated that, in addition to children's pretest PCC scores, the total number of therapy sessions received over the year, as well as the total number of individual therapy sessions, was a significant predictor. There was a positive relation between the total number of therapy sessions and PCC gain such that children who received more therapy sessions over the year demonstrated greater PCC gain compared to children who received fewer therapy sessions throughout the year. In many ways, this is a logical result, especially considering the "more is better" suggestion from several recent studies (Allen, 2013; Mullen & Schooling, 2010; Schooling et al., 2010). For instance, Allen (2013) specifically manipulated session frequency for children with SSDs and found that children who received therapy three times per week experienced more gains—also measured by PCC—compared to children who received therapy only once per week. The effect reported in Allen was maintained after both the same amount of time (i.e., 8 weeks) as well as after the same number of sessions (i.e., 24 sessions). Note, however, that all participants ultimately received the same total number of sessions overall. Children in this study were treated either in individual sessions or in a session with a peer. The impact of the individual versus paired session was not evaluated.

In this study, we found that the relation between the number of individual therapy sessions and PCC gain was negative, such that children who received more individual sessions demonstrated less PCC gain throughout the year. This result was surprising, as there is very little empirical support for the benefits of group compared to individual treatment sessions (but see Skelton & Richard, 2016). Indeed, Cirrin et al. (2010) conducted a systematic review of the literature to determine the influence of school-based service delivery models (direct vs. indirect, group vs. individual, pull-out or push-in, etc.) on a variety of speech and language outcomes for school-aged children. In their review of 255 articles, there were only five available studies that empirically tested the impact of service delivery models on child outcomes; none of these five studies examined speech sound production or speech intelligibility. Only two

of the five studies reported on the differences between group and individual therapy sessions, with no statistically significant difference between the two. Since then, there continues to be a dearth of literature examining the differences in school-based service delivery models and how those models influence speech sound production or intelligibility.

It continues to be the case, however, that school-based SLPs provide services in group settings more so than in individual settings (Brandel & Loeb, 2011; Mann Brumbaugh & Smit, 2013). Presumably, group therapy sessions afford more naturalistic opportunities for children to practice their speech sounds. Perhaps this small group setting, with practice in both producing accurate speech sounds and hearing peers practice accurate speech sound production, yields better gains over time. This was indeed the case in Skelton and Richard (2016), who provided group-based speech sound treatment and encouraged children to practice their sounds subvocally while a peer was taking his/her turn. Note that, in this study, all children in the groups were working on the same target speech sound; however, it is common for treatment groups to be more heterogeneous (Mann Brumbaugh & Smit, 2013).

Group therapy could also be beneficial because it mimics, on a smaller scale, the types of learning environments that children experience in the classroom. Thus, perhaps group therapy sessions allow for the processing and learning of new material because it takes place in a more familiar setting. By contrast, individual sessions may be too decontextualized from the educational setting. In the present sample, however, speech sound severity was not related to receipt of individual sessions. Currently, then, it is unknown why some children received more individual sessions than others. It is plausible that individual sessions are provided to help improve response to therapy. This might include children with more challenging behaviors or children who require a higher dosage of trials due to motor speech difficulty and/or atypical errors. This would certainly be an important direction for future research.

Limitations

Although this study offers robust clinical implications, there are limitations to be considered. First, these data were obtained from a larger study focusing on children with language impairments receiving services in school-based settings. As such, the pretest and posttest assessment battery was largely focused on language instead of speech sound production abilities. We do not have specific data such as a standardized test score, stimulablity (Shriberg et al., 1994), and consistency (Arndt et al., 1971; Baer & Winitz, 1968; Forrest et al., 1997), each previously shown to have predictive value for change in speech sound production. These measures may also have been more sensitive to capturing change over time, as compared to our measure of PCC (e.g., Kearney et al., 2015). Related, our collection of speech samples was naturalistic and included a wordless picture book. As a result, there was variability among the samples, which included word count and exact number of minutes. We also did not, for the purpose of answering the current research questions, conduct a micro-analysis of word or phoneme type within the sample. This would be an interesting future direction to determine how lexical and phonological qualities of speech samples contribute to metrics such as PCC. Next, participating SLPs were aware that the data that they were tracking would be used for research purposes. Thus, it is plausible that reports of time in therapy could be inflated or impacted. However, our data included enough variability to suggest that SLPs reported honestly and accurately about their time spent in therapy.

Indeed, as a function of the exploratory nature of this work, our sample did not include a control group. However, our work reflects the realistic growth that may be seen in the course of one academic year. Other school-based studies have included a delayed treatment group (e.g., Sacks et al., 2013; Skelton & Richard, 2016). This approach may allow for the use of a control group, without withholding required services under the Individuals with Disabilities Education Act. Finally, future research should also consider the role of SLP-level variables, such as caseload size, years of experience, and job satisfaction, as these three factors have been linked to service provision decisions and therapy quality (Biancone et al., 2014; Katz et al., 2010; Swaminathan & Farquharson, 2018). It is possible that some of the therapy-level factors examined in the current study are more linked to the specific SLP than to the child. In the current investigation, we were unable to determine why children received the parameters of therapy that they did, or what specific constraints faced each SLP. However, these are malleable factors that can and should be adjusted, particularly given our findings.

Clinical Implications

Overall, this investigation includes clinically important results regarding the influence of business-as-usual school-based service delivery on changes in speech sound production. First, results from this study suggest that it is important to consider the child's speech sound severity when considering potential gains in PCC. Second, it appears that age and language do not predict PCC gain, which means that children as young as 5 years and in kindergarten, with varying levels of language ability, can benefit from speech sound intervention. Finally, when planning treatment, our results suggest that group sessions and more frequent sessions per year may result in more change over time; however, future empirical studies should systematically manipulate these components of therapy to best understand "what works for whom." Doing so will also allow for a better understanding of how to optimize treatment for the myriad of SSD profiles that may be seen in school-based settings. Although the extant literature is fairly rich with respect to specific speech sound interventions, the ecological validity of those studies can often not withstand the demands of a school-based setting. As such, this study makes an important contribution to the extant literature as it considers the environmental variables in school-based settings.

Importantly, these environmental variables are malleable factors over which most SLPs have control. The long-term goals of this line of work are to make it easier for SLPs to more precisely tailor intervention to capitalize on child- and therapy-level factors that are now known to impact gains in speech sound production.

Acknowledgments

This research was supported by Grant R324A090012 from the U.S. Department of Education, Institute of Education Sciences awarded to Laura M. Justice. We acknowledge the efforts of the Speech Therapy Experiences in the Public Schools project staff and research assistants, including Mary Beth Schmitt, Karie Wilson, Allison Alexander, and Kate Fresh. We are particularly thankful to the speech-language pathologists, classroom teachers, families, and students who participated in this study.

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