Predictors of Phonological Change Following Intervention

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To date, predictor variables strongly associated with phonological change as a result of intervention have not been identified. The purpose of this study was to determine the best predictor or combination of predictors of change in percentage of consonants correct (PCC; L. D. Shriberg & J. Kwiatkowski, 1982) as a result of speech-language intervention for a group of 20 participants and to replicate this procedure with a second group of 20. Participants were preschool children, ages 3:0 (years;months) to 5:11, with impairments in phonology and morphosyntax who received intervention focused on both phonology and morphosyntax in different goal attack configurations. The relationship of predictor variables chronological age, inventory size, error consistency, and expressive language to the criterion variable, change in PCC, was investigated. In both the initial study and the replication, the mean change in PCC following a 24-week intervention period was 13.1%. In the initial study, error consistency and a finite morpheme composite (FMC; L. M. Bedore & L. B. Leonard, 1998) accounted for 52% of the variance for the criterion variable. Error consistency at the first step in the regression accounted for 31.6% of the variance. In the replication, error consistency was the only variable related to PCC change, again accounting for 31% of the variance. Further research examining overall error consistency is warranted.

Key Words: phonology, intervention, prediction, consistency
Much of the prediction research in phonological impairment has focused on identifying variables that predict which children will normalize with and without intervention. In a number of studies, risk factors such as socioeconomic status, auditory discrimination ability, expressive and receptive language skills, intelligence, and psychosocial influences have been explored as possible predictors (Andersland, 1961; Baker & Cantwell, 1987; Bishop & Edmundson, 1987; Dickson, 1962; Farquhar, 1961; Parlour, Broen, & McGue, 1989; Petit, 1957; Shriberg & Kwiatkowski, 1988; Shriberg, Gruber, & Kwiatkowski, 1994; Steer & Drexler, 1960; Tyler & Edwards, 1986). Of these variables, lowered cognitive and language comprehension scores have been shown to lead to the poorest speech outcomes (Bishop & Edmundson, 1987; Shriberg & Kwiatkowski, 1988); however, even these variables in conjunction with speech improvement have shown only moderate predictive power.

Although normalization studies have specified an age by which maximum phonological change should occur (Shriberg, Kwiatkowski, & Gruber, 1994; Shriberg, Gruber, & Kwiatkowski, 1994), age has not been examined as a predictor of change from intervention. Because it is not known if there is a differential response to treatment according to age and because children have different developmental trajectories, age would be a potentially important predictor variable. Further, in a study of children with moderate-to-severe phonological disorder who did not receive treatment, Shriberg, Gruber, and Kwiatkowski (1994) found that during a 5-year period of speech sound normalization there were 1- to 2-year periods of more rapid growth. Thus, when treatment spans a period as long as a year, age may be a variable that is predictive of change from intervention.

Because of the large variability inherent in predicting intervention success, Kwiatkowski and Shriberg (1998) established the capability-focus framework in an effort to account for individual differences in intervention outcomes. In addition to capability, which was reflected in inventory size (IS) and/or pretreatment PCC, a behavioral rating of motivation (i.e., measure of focus) from a five-level focus task was entered in the predictive equation. Results indicated that a child’s speech capability at the onset of intervention was strongly associated with intervention outcome, although this construct alone was insufficient to make such predictions. When focus was examined in the context of pre- and postintervention measures, it was found that low focus, which acts as a constraint on a child’s learning, was a second statistically significant predictive measure.

Other studies focusing on the relationship among predictor variables and phonological change from intervention have found some support for the predictive value of consistency and stimulability. Shriberg, Kwiatkowski, and Gruber (1994) stated that although stimulability measures can be beneficial in selecting and sequencing treatment targets, they produce high rates of false positives and negatives at the level of predicting individual improvement.

The (in)consistency with which a child substitutes, omits, or adds a particular phoneme for an intended target phoneme in a given position may be an important aspect of determining phonological change. Baer and Winitz (1968) examined the association between children’s amount of consistency and subsequent acquisition of specifically treated phonemes. Children were divided into three groups according to a minimal, moderate, or maximal number of errors they exhibited in producing the target phoneme /v/. Children were then trained on two syllables beginning with the phoneme /v/. Subsequent analysis of these children’s phonological systems following specific sound training revealed that inconsistency, in this case being a child’s high number of production errors for a particular phoneme, did not predict generalization to new linguistic contexts. Arndt, Elbert, and Shelton (1971) found instead that consistent scores in imitation tasks for specific phonemes from early treatment sessions were predictive of long-term treatment outcomes.

Similarly, Forrest, Dinnsen, and Elbert (1997) found that although PCC measurements prior to intervention were not reliable indicators of speech sound learning, a child’s substitution pattern (consistent vs. inconsistent) for the error sound that was treated did prove to be strongly related to improvement. Children with a consistent substitute across word positions benefited from treatment of the error sound in a single word position. Such children in their study learned the sound targeted during intervention and generalized this knowledge to other word positions. On the other hand, children with inconsistent substitutes learned the treated sound, but only in the treated word position. Consequently, Forrest et al. concluded that pretreatment substitution patterns may hold predictive value in learning and generalization patterns.

Expressive language as a potential predictor of change from intervention has received limited investigation. It may be an important variable, because as high as 75% and an average of 60% of children with speech delays may have accompanying expressive language difficulties (Shriberg & Austin, 1998; Shriberg & Kwiatkowski, 1994). Further, children with phonological/articulation problems but normal expressive language have been shown to normalize their articulation more frequently and experience fewer academic difficulties as compared to children with both speech and expressive language impairments (Baker & Cantwell, 1987; Hall & Tomblin, 1978; Tyler & Edwards, 1986).

To summarize, research in developmental phonology has focused more on identifying variables associated with children who will normalize than on variables that are predictive of individuals who will change as a result of intervention. Identifying variables that predict response to intervention is hampered by the large amount of variability in children’s initial status, as well as their responses to the intervention process. Kwiatkowski and Shriberg (1998) suggested that there is a need for a measure of phonological status or capability that is relevant for treatment efficacy issues. Although consistency with respect to a specific phoneme shows potential as a predictor of change for that phoneme (Baer & Winitz, 1968; Forrest et al., 1997), overall error consistency of a child’s phonological system remains unexplored. In addition, use of a global measure such as PCC, PPK, or intelligibility would be
indicative of system-wide change resulting from intervention as opposed to local change measured by generalization for only the targets of intervention. There is a need for additional research in the area of predicting phonological change following intervention. Further, it is appropriate to examine a limited number of variables to determine which, if any, serve as predictors of phonological change following treatment. The purpose of this study was to determine the best predictor or combination of predictors of change in PCC as a result of speech-language intervention for a group of 20 participants and to replicate this procedure with a second group of 20. The research question was as follows: What is the relationship of chronological age (CA), IS, error consistency, and/or expressive language to change in PCC as a result of speech-language intervention?

**Initial Study**

**Method**

**Participants**

Twenty preschool children, ages 3;0 (years;months) to 5;11 (mean age = 4;3), with impairments in phonology and morphosyntax served as participants. All were enrolled in the early childhood programs in Washoe County (Nevada) School District, and as such met state criteria for classification as having special educational needs, with speech-language impairment being the primary category for classification. Children were referred as potential participants via their classroom teacher and/or speech-language pathologist. These children were participating in a larger study examining the effect of different goal attack strategies for targeting both speech and morphosyntax in children with co-occurring speech and morphosyntactic disorders. Vertical, simultaneous, and cyclical strategies for sequencing multiple goals in both phonology and morphosyntax were compared. Thus, different scheduling configurations were dictated by the design of the larger study, but all children in the initial study and replication received the same types of intervention for the same number of both phonological and morphosyntactic goals. Further, with respect to possible effects of these goal attack strategies on the criterion variable, there were no significant differences in PCC change between the different strategies, $F(3, 35) = 0.21, p = .891$.

To be included in this study, participants had to meet the following criteria:

1. Documentation of expressive language scores at least 1 SD below the mean on the Preschool Language Scale--3 (PLS-3; Zimmerman, Steiner, & Pond, 1992) or the Clinical Evaluation of Language Fundamentals--Preschool (CELF-P; Wiig, Secord, & Semel, 1993), or a mean length of utterance (MLU) in morphemes greater than 1.5 SDs below the mean based on Leadholm and Miller’s (1993) normative data;
2. Documentation of speech performance at least 1 SD below the mean on the Bankson-Bernthal Test of Phonology (BBTOP; Bankson & Bernthal, 1990);
3. Documentation of nonverbal cognitive functioning within 1.5 SDs of the mean on the Columbia Mental Maturity Scale (CMMS; Burgemeister, Blum, & Lorge, 1972);
4. Normal hearing, as indicated by pure-tone screening;
5. Normal functioning on oral motor assessment (Robbins & Klee, 1987); and
6. Neurological, behavioral, and motor skills reported within normal limits.

Because expressive morphosyntax was a focus of this study, some children selected had receptive scores within 1 SD of the mean, as long as their expressive scores fell below 1 SD. Children could also qualify as participants if they had standard scores within the normal range on the PLS-3 but considerable morphosyntactic deficits as evidenced by an MLU that was greater than 1.5 SDs below the mean. The PLS-3 does not have a strong emphasis on morphosyntax, such that it is possible for children with morphosyntactically based language impairments to perform within normal limits on it. The participants whose expressive scores fell within the normal range had morphosyntactic deficits documented by an MLU greater than 1.5 SDs below the age mean. These participants were referred for the study by their school speech-language pathologist because they had been identified to receive or were receiving intervention for morphosyntactic difficulties.

The children’s mean expressive language standard score was 76.85, their mean receptive standard score was 84.6, and their average MLU was 2.8. BBTOP results revealed a mean standard score for the Word Inventory of 69, for the Consonant Inventory of 68, and for the Phonological Process Inventory of 69. CMMS administration to the 20 children revealed a mean nonverbal IQ of 104.

**Procedures**

Each participant’s speech and language performance was measured at the beginning, middle, and end of treatment in accord with the larger study design. Data were collected 2–4 weeks before the onset of treatment (September), in the middle of the intervention period (February), and 2 weeks posttreatment (May). For the purposes of the present study, only the data collected at the initial and final samples were analyzed. Pre- and postintervention measurements were obtained from administration of the BBTOP, supplemented by 15 additional words (primarily nouns) to ensure that the 23 consonants occurred a minimum of three times each in initial and final word positions. The BBTOP and supplementary words were administered by speech-language pathology graduate assistants or certified SLPs in small, quiet rooms in a university clinic or the child’s preschool environment. Each sample was audiotaped using a Marantz PMD 430 with two external lapel microphones. Using the International Phonetic Alphabet, broad transcriptions were made from audiotapes and subsequently entered into the Interactive System for Phonological Analysis (ISPA; Masterson & Pagan, 1994). ISPA is a computer analysis program used to generate quantitative data including percentages of phonological process occurrence, frequency of phones in the phonetic inventory, analysis of consonant substitutions, and PCC.
In addition, spontaneous language samples comprising at least 200 utterances were collected and analyzed. Samples were gathered in the context of examiner and child interaction with a Playmobil house and accessories. Samples also included narratives based on books in the *Car*! series by Alexandra Day. A minimum of three obligatory contexts for each of Brown’s (1973) 14 grammatical morphemes were provided. Samples were subsequently transcribed and coded in accordance with protocol from the Kansas Language Transcription Database manual (Howe, 1992). The Systematic Analysis of Language Transcripts program (SALT; Miller & Chapman, 2000) was then used to determine MLU in morphemes, Brown’s stage, and each occurrence of correct, incorrect, and omitted grammatical morphemes for each participant.

**Variables**

The four predictor variables examined in this study included IS, error consistency index (CI), finite morpheme composite (FMC), and CA. The criterion variable was PCC change.

IS was selected as a measure of the number of different sounds a child could produce, regardless of their accuracy with respect to the target sound. IS was chosen because Shriberg and colleagues (Kwiatkowski & Shriberg, 1993, 1998) found in their predictive studies with the capability-focus framework that consonant inventory, alone, led to accurate classification of speech outcomes in discriminant function analyses. ISPA printouts were used to compile a phonetic inventory for each child. In accordance with previous research (Dinsen, Chin, Elbert, & Powell, 1990; Dyson, 1988; Forrest et al., 1997; Stoel-Gammon & Dunn, 1985), a consonant was included in the participant’s phonetic inventory if it was produced a minimum of two times in a position for both the initial position inventory and the final position inventory. An IS was then compiled by calculating the total number of different phones in each child’s inventory across positions. In other words, the number representing each child’s IS did not specify in which position(s) of the word a child could produce a specific phone, but just that he or she had phonological knowledge of that particular sound. A total of 23 phonemes were assessed.

An overall error CI was used as a measure of the total number of different sound substitutions/omissions each participant made across word positions. ISPA printouts were examined for speech sound substitution errors in order to calculate a pretreatment error consistency score for each participant. The error CI was defined as a raw number that reflected the combined total number of different substitutions for each of the 23 phonemes, across all word positions. That is, the total number of different phonemes used as substitutes, regardless of position, for each sound was determined. These were summed across all 23 phonemes and an overall error consistency score was obtained for each participant. A low error consistency score for a child reflected a more consistent phonological system, although correct phoneme production may or may not have been any more evident than in a child with highly inconsistent errors and, thus, a high error consistency score. A participant with a low error consistency score simply made fewer and more consistent substitutions for all target phonemes.

The FMC was selected as an expressive language measure. FMC represents the combined percentage correct usage of the following finite morphemes: regular past tense -ed, third person singular regular -s, contractible and uncontractible copula be, and contractible and uncontractible auxiliary be forms (Bedore & Leonard, 1998). This measure was selected as a possible predictor because each participant in this study had a deficit in morphosyntax in addition to his or her phonological disorder and, by design of the larger scale study, received both phonology and language intervention. Further, the language intervention targeted finite morphemes for the most part. These morphemes also interact with phonological patterns. For example, targeting a finite morpheme such as third person singular entails an indirect focus on the correct production of clusters in the final position of words (e.g., ts, dz, nd, kt). Finite morpheme percentages were obtained by calculating the frequency of occurrence of the finite morphemes across all obligatory contexts from frequency data provided for each morpheme by SALT.

The fourth predictor variable, CA, was selected as a measure accounting for the natural maturation of each participant during the course of intervention.

The criterion variable, PCC change score, was selected as a measure of global phonological change following intervention. This score was obtained by calculating the gain in PCC from Sample 1 (September) to Sample 3 (May). PCC was selected as the criterion variable and not a predictor variable in this study for several reasons. First, when PCC was used alone as a predictor of speech outcome following intervention, it was not strongly associated with treatment progress (Forrest et al., 1997; Kwiatkowski & Shriberg, 1993). Secondly, PCC was one of the only variables from among numerous speech (consonants, features, vowels-diphthongs) and prosody-voice profile analyses, that differentiated a sample of children who normalized their phonologies over 1 year and a sample that did not (Shriberg, Kwiatkowski, & Gruber, 1994). Third, PCC is a global measure encompassing constructs of intelligibility, handicap, and disability (Shriberg & Kwiatkowski, 1982). Because PCC reflects intelligibility, at least in part, and because intelligibility scores are so influenced by linguistic, contextual, and listener lexicalization factors (Weston & Shriberg, 1992), particularly in the population with interacting morphosyntactic deficits in the present study, PCC and not intelligibility was selected as the criterion variable.

**Reliability**

Following the collection of spontaneous language samples for both pre- and posttreatment measurements, a trained research assistant listened to the audiotapes two times, initially transcribing each child’s utterances and subsequently coding and revising them. Trained graduate student research assistants then listened to the audiotapes supplemented by the transcript texts and made appropriate
corrections on glosses and codes. The original research assistant served as the expert coder in determining final results if coding and/or transcription discrepancies occurred. Transcription agreement, reflected below as the number of discrepancies in transcription of child utterances divided by the total number of words in each sample, was 99% across samples, with a range of 95% to 100%.

After a research assistant collected pre- and posttreatment speech samples, a secondary judge completed broad transcriptions to check for coding agreements. Point-to-point reliability was calculated based on each judge’s transcription of each consonant. Segmental transcriptions that were identical in place, manner, voicing, and nasality were coded as agreements. The overall mean for speech transcription agreement was 90%.

Phonetic inventory sheets were developed and IS was calculated and later recalculated a second time by the author. Intragrade agreement was 98% across all participants. Error consistency scores were then derived, with an intragrade agreement of 99%. Next, the principle investigator of the larger scale study calculated the IS and consistency score for 20% of the samples to determine interjudge reliability. Results were compared, and IS reliability was found to be 100% across samples (pre- and posttreatment). Consistency score reliability was 99% across samples.

**Intervention Procedures**

The general design of the larger scale study, in which the present children participated, focused on goal attack strategies in which different configurations were used to target phonology and morphosyntactic goals. The 20 children in the initial study were randomly assigned to one of two combination intervention strategies: (a) an alternating strategy in which phonology and morphosyntactic goals alternated on a weekly basis for 24 weeks or (b) a simultaneous strategy in which phonology and morphosyntactic goals were integrated within activities in every session. Children were seen individually for one 30-min session at each of six school sites, working with four certified SLPs and four graduate student interns.

Regardless of the type of intervention, four phonology goals and four language goals were selected for each child and scheduled in a cycles format. Goals for each participant were chosen on the basis of results from analysis of the initial speech and language samples. Language goals addressed morphosyntactic structures and phonological goals addressed both segmental and syllable structure forms. Children grouped together shared the same goals, which were targeted in both the individual and group sessions. Goal selection was based on needs of the majority of children in a group. Phonological goals included sounds from adjacent categories in Shriberg’s (1993) developmental sequence (e.g., early 8, middle 8, late 8). For example, target combinations such as /f, s, t/ and /l, f, k/ represented phonemes from the middle 8 (/k, f, t/) and late 8 (/s, f, l/) categories. Phonology goals were selected by taking into account overall phonetic inventory, phonological processes used >35–40%, sound classes affected, word/syllable structure, substitution analysis, and positional constraints. Each child had four goals, with one of those focused on cluster targets for cluster reduction/simplification error patterns. Each participant’s phonological goals are shown in the Appendix.

Phonological intervention procedures involved both child-centered and clinician-directed activities. Each session included auditory awareness activities, conceptual activities, production practice activities, and a phonological awareness activity. The majority of each session focused on production practice activities with awareness and conceptual activities taking only 5–10 min of the session. Auditory awareness activities focused on heightening children’s awareness of the target sound and directing their attention to the sound’s auditory-acoustic attributes.

Activities included listening to word lists and books containing a high number of occurrences of the target sound. Production practice activities, both drill play and naturalistic, were designed to help establish production of new sounds and to facilitate practice of those sounds in communication contexts. Clinicians attempted to elicit 24–32 target productions per session. Drill play activities involved direct elicitation using phonetic placement, shaping, and cueing techniques, and naturalistic activities provided opportunities for production of target sounds in communication contexts. In naturalistic activities, incorrect productions were immediately recast by the clinician, whereas in drill play activities, clinicians responded to incorrect responses by providing a model and requesting an imitation. The phonological awareness activity was designed to stimulate preliteracy skills by increasing children’s awareness of the speech sound system through techniques including rhyme detection and initial sound identification. Whenever possible, pictures containing the target sound were supplemented by print in order to enhance literacy skills. All clinicians were provided with the same books/word lists, stimulus pictures, naturalistic scripts, and phonological awareness materials, which were all accompanied by written directions for their use, to ensure reliable implementation across clinicians. A review of 62.5% of the participants’ individual data records indicated that children averaged 36 productions of their target sound per session.

Language goals addressed morphosyntactic structures (i.e., finite morphemes such as regular past tense -ed, third person singular -s, contractible and uncontractible copula be, and contractible and uncontractible auxiliary be forms). Language goals focused on morphological targets because, overall, they were more problematic for the children in the study than other types of language targets (e.g., sentence structure, etc.). Morphemes targeted were used with 0–50% accuracy in the initial language sample and were from adjacent stages in Brown’s (1973) stage sequence for grammatical morpheme acquisition. It should be noted that the need to have similar goals for all the children in a group sometimes superceded the 0–50% criterion.
Language intervention procedures entailed language activities revolving around a central theme such as food, animals, or water. Each session included auditory awareness activities, focused stimulation activities, and elicited production activities (Camarata, Nelson, & Camarata, 1994; Cleave & Fey, 1997; Fey, Cleave, Long, & Hughes, 1993; Nelson, 1989). Detailed written scripts were created for all activities for each session to ensure reliable implementation of the intervention across clinicians (Haskill, Tyler, & Tolbert, 2001). Auditory awareness activities were designed to provide children with examples of the target morpheme through stories, songs, and books. In activities using focused stimulation techniques, the children were provided with numerous models of target structures through the course of natural communicative interactions. These involved recasts and expansion of child utterances and opportunities to use target forms in response to contextually relevant questions or prompts. Elicited production activities were designed to elicit 20–30 productions of the particular target morpheme. These activities were hierarchically sequenced by the level of support provided by the clinician progressing from Cycle 1 to Cycle 3. Forced choice tasks were used in Cycle 1 to elicit target productions. In this case, the clinician obligated the production of a morpheme by providing the child with the choice of two responses, both of which contained the target (e.g., “The boy eats or cries?”). In Cycle 2, which entailed the presentation of cloze tasks, the clinician began an utterance and paused prior to the target form to give the child the opportunity to produce it (e.g., “What does Bobby do? He __”). Preparatory sets, used in Cycle 3, involved techniques whereby the clinician indirectly modeled for the child how to use target forms and subsequently gave the child a turn to form his or her own similar production.

Results

Consonant with the purpose of this study, four predictor variables, CA, IS, overall error consistency (CI), and expressive language (FMC), were regressed on the criterion variable (PCC change) in order to identify the best predictor or combination of predictors of change in PCC as a result of speech-language intervention. A multiple regression analysis using a hierarchical-forward procedure was applied to data from a group of 20 participants.

### TABLE 1. Means and standard deviations for predictor and criterion variables from the initial study and replication.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Initial Study</th>
<th>Replication</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>CA</td>
<td>52.55</td>
<td>9.54</td>
</tr>
<tr>
<td>IS</td>
<td>16.45</td>
<td>2.65</td>
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<tr>
<td>CI</td>
<td>36.60</td>
<td>15.56</td>
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<tr>
<td>FMC</td>
<td>38.17</td>
<td>22.90</td>
</tr>
<tr>
<td>PCC change</td>
<td>13.10</td>
<td>6.63</td>
</tr>
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</table>

Note. CA = chronological age; IS = inventory size; CI = overall error consistency index; FMC = finite morpheme composite; PCC = percentage of consonants correct.

Means and standard deviations for all five variables are displayed in Table 1. The mean change in PCC was 13.1, with change scores ranging from 4% to 26% and a standard deviation of 6.63%. The correlation matrix for the four predictor variables and the criterion variable is displayed in Table 2.

Predictors CI and FMC accounted for almost 52% of the variance in PCC change, with $R^2 = .516$; $F(1, 18) = 8.3, p = .01$. CI was brought into the regression equation at Step 1, with $R^2 = .316$. Analysis terminated after Step 2, with neither CA nor IS contributing enough to the remaining variance in PCC change to be entered into the equation with a probability of $F$-to-enter (PIN) of .05.

### Replication

#### Method

**Participants**

The 20 participants in the replication study met the same selection criteria as described for the initial study participants. Their mean age was 4;2, mean expressive language standard score was 77.05, mean receptive language score was 82.55, and average MLU was 2.59. BBTOP results revealed a mean standard score for the Word Inventory of 69.55, for the Consonant Inventory of 68.5, and for the Phonological Process Inventory of 71.05. The mean CMMS score was 102.

The 20 children in the replication were randomly assigned to one of two block intervention strategies: (a) a 12-week block of phonological intervention followed by a 12-week block of morphosyntactic intervention or (b) vice versa, beginning with a 12-week block of morphosyntactic intervention. It should be noted that although the intervention was configured differently from that of the initial study, children in the replication all had the same number of goals scheduled in a cycles format and the same morphosyntax and phonology interventions were used in each different strategy. All other aspects of the intervention were identical to that described for the initial study.

#### Procedures

Data collection and analysis procedures were also identical to those previously described.

### TABLE 2. Correlation matrix for the four predictor variables and PCC change, the criterion variable, from the initial study.

<table>
<thead>
<tr>
<th>Variable</th>
<th>CA</th>
<th>IS</th>
<th>CI</th>
<th>FMC</th>
<th>PCC Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA</td>
<td>1.00</td>
<td>.311</td>
<td>−.273</td>
<td>.061</td>
<td>−.250</td>
</tr>
<tr>
<td>IS</td>
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<td>−.669</td>
<td>.362</td>
<td>−.216</td>
</tr>
<tr>
<td>CI</td>
<td>−.273</td>
<td>−.669</td>
<td>1.000</td>
<td>−.521</td>
<td>.562</td>
</tr>
<tr>
<td>FMC</td>
<td>.061</td>
<td>.362</td>
<td>−.521</td>
<td>1.000</td>
<td>.089</td>
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<tr>
<td>PCC change</td>
<td>−.250</td>
<td>−.216</td>
<td>.562</td>
<td>.089</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Note. CA = chronological age; IS = inventory size; CI = overall error consistency index; FMC = finite morpheme composite; PCC = percentage of consonants correct.
Table 3. Correlation matrix for the four predictor variables and PCC change, the criterion variable, from the replication.

<table>
<thead>
<tr>
<th>Variable</th>
<th>CA</th>
<th>IS</th>
<th>CI</th>
<th>FMC</th>
<th>PCC Change</th>
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<tr>
<td>CI</td>
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<td>−.682</td>
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<tr>
<td>FMC</td>
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<td>.614</td>
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<td>1.000</td>
<td>−.289</td>
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<tr>
<td>PCC change</td>
<td>−.106</td>
<td>−.422</td>
<td>.557</td>
<td>−.289</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Note. CA = chronological age; IS = inventory size; CI = overall error consistency index; FMC = finite morpheme composite; PCC = percentage of consonants correct.

Results

The replication examined CA, IS, overall consistency (CI), and expressive language (FMC) as they related to PCC change following intervention. Means and standard deviations for each variable are displayed in Table 1. The mean change in PCC was 13.1, essentially identical to that of the initial study. Change scores ranged from −1% to 46%, with a standard deviation of 10.79%.

To assess change in PCC as a result of intervention, data were analyzed with a multiple regression procedure using the hierarchical-forward method. Table 3 displays the correlation matrix for the four predictor variables and PCC change, the criterion variable. Analysis terminated after Step 1 with the inclusion of only the CI predictor. By itself, CI accounted for 31% of the variance in the criterion ($R^2 = .31$), $F(1, 18) = 8.09$, $p = .01$. The predictive value of CI in the replication data mirrored the 31.6% of variance obtained in the initial study.

After the criterion variance preempted by CI was partialled out, no other predictor variable (IS, FMC, or CA) accounted for enough of the remaining criterion variance (PIN = .050) to be entered into the equation. Neither CA nor IS nor FMC made a statistically significant contribution to prediction of the criterion and, therefore, they were not entered into the regression equation. Because all other predictors were excluded from the equation, the final outcome of regression analysis, after adjusting for rounding errors, was equivalent to the bivariate relationship between the CI predictor and the PCC change criterion.

General Discussion

The purpose of this investigation was to determine the predictive value of CA, phonetic IS, error consistency, and FMC as they relate to change in PCC as a result of intervention. In the initial study, error consistency and a measure of expressive morphology, FMC, together accounted for approximately one half of the variability in PCC change demonstrated by the participants. Error consistency itself accounted for 31% of the variance in PCC change evidenced by the initial sample of 20 participants. No other variable yielded statistically significant contributions to the prediction equation. In the replication, error consistency was again found to account for 31% of the variability in PCC change, with no other statistically significant predictors.

The fact that error consistency was significantly related, with a moderate-strength correlation to PCC change, and that this finding was replicated with the identical result in a second sample indicates the potential predictive value of such a measure. Consistency has been relatively unexplored and, when examined, has been isolated to specific phoneme substitutions rather than overall consistency of a child’s sound system, as in the present study. Previous researchers (Baer & Winitz, 1968; Madison, 1979; Powell, Elbert, & Dinnsen, 1991; Shriberg & Kwiatkowski, 1994) have not found support for the consistency of specific phonemes as a predictor of speech sound learning. On the other hand, Forrest et al. (1997) found some support for the prognostic value of the consistency of children’s substitution patterns for the error sound treated. Similarly, the results of the present investigation provide evidence for overall error consistency as a predictor of PCC change following intervention. In this case, a measure of error consistency (CI) for each child was determined by calculating the total number of different sounds substituted for each target phoneme across all word positions. Because of limited available research and the relatively moderate proportion of variance (31%) accounted for by the error consistency variable, additional research examining overall error consistency is warranted.

In the initial study, CI and FMC together accounted for approximately 52% of the shared variance in the criterion variable (PCC change). In the replication study, FMC did not make a significant contribution to the prediction equation. It is not clear what contribution FMC, by itself, makes in predicting PCC change. Continued research on the possible predictive value of FMC is needed.

The findings of the present study are consistent with results from the prediction research to date in developmental phonological disorders: There appears to be no one predictor variable strongly associated with phonological change following intervention. In the present study, CA, phonetic IS, and expressive language skills as determined by FMC were not found to be strong predictors of PCC change after intervention. Variables previously studied have included speech and prosody-voice status, occurrence of phonological processes, demographic status, direct and indirect intervention variability, hearing status, adequate speech mechanism and function, cognitive–linguistic development, psychosocial influences, CA, socioeconomic status, auditory discrimination ability, intelligence, consistency of sound substitutes, stimulability, and initial treatment success (Andersland, 1961; Arndt et al., 1971; Baer & Winitz, 1968; Baker & Cantwell, 1987; Bishop & Edmundson, 1987; Dickson, 1962; Farquhar, 1961; Forrest et al., 1997; Parlour et al., 1989; Petit, 1957; Reid, 1947; Shriberg & Kwiatkowski, 1988, 1994; Steer & Drexler, 1960; Tyler & Edwards, 1986).

In the present study, change was defined differently and different predictors were examined in comparison to those in the existing research; however, essentially the same results were obtained. Two thirds of PCC change could not be accounted for by the examined variables, although error consistency did account for 31% of the overall change in PCC evidenced by the children studied. To date, an
assortment of criteria for actual phonological change has been used. For example, Shriberg and Kwiatkowski (1994) defined normalization as the standard for tested variables to achieve predictive value. In the present study, PCC was used as a measure of change; it is a less stringent requirement than normalization and a more global objective measure than treated sound learning for determining the relationship between phonological change and a number of variables.

A limitation of the present study is in the different goal attack configurations and their focus on both phonology and morphosyntactic goals dictated by the larger intervention project. It is important to note again that the goal attack strategies did not differentially impact phonological change. Tyler, Lewis, Haskill, and Tolbert (2002) did show, however, that there were cross-domain effects of the morphosyntax intervention on phonological change in the block configurations. After one 12-week block, phonological change was as great for the group receiving the morphosyntax intervention as it was for the group receiving phonological intervention. The design of the present study did not control for the effects of morphosyntax intervention on phonological change, and although there were no differences in that change, it is not known to what extent the morphosyntax intervention influenced phonological change.

Clinical Implications

An unexpected finding of the present study was that a highly inconsistent system was associated with greater PCC change than a consistent system. Thus, children with greater scores on the error CI showed greater PCC change as a result of speech-language intervention. The specific interventions used in this study may be one explanatory factor for this finding. Children received 12 weeks of a morphosyntactic intervention focused on finite morphemes in addition to 12 weeks of a hybrid phonological intervention. The morphosyntactic intervention not only provided exposure to phonemes in the context of conversational speech, but also provided practice with specific final clusters used to mark morphemes reflecting tense and agreement (e.g., past tense -ed; kt, ft, rd, nd). It is possible that an indirect focus on clusters, a more marked aspect of phonology, may have facilitated other changes in the phonological system on individual segments (Gierut & Champion, 2001). The more diversified stimuli and varied opportunities for productions in the language approach may also have facilitated phonological change that was more widespread than that from the hybrid phonological approach that focused on specific phonemes.

Because it is virtually impossible to teach a child every target sound in every relevant word and word position, researchers continue to search for the answer regarding what best predicts phonological change. Determining such a predictor, or combination thereof, would assist speech-language pathologists in establishing the most appropriate and efficient targets as goals for treatment. Research examining error consistency in conjunction with different intervention targets (i.e., treating highly consistent sounds in error vs. treating error sounds with little to no consistency) is warranted. In addition, it would be appropriate to establish a control group of participants in future studies to examine the predictive value of error consistency for PCC change after a given period of time without intervention.

In conclusion, the search to find predictors of phonological change in order to aid in the determination of intervention approaches and treatment targets is an ongoing process. Results from the present study are consistent with those obtained from the available research on developmental phonological disorders, showing that there is no one strong predictor of phonological change.

Although three of the variables (i.e., CA, phonetic IS, and expressive language skills determined by FMC) did not significantly contribute to the variability in PCC change, overall error consistency was found to account for approximately one third of the phonological change evidenced. Because there is limited support for the prognostic value of any specific variable in relation to phonological improvement, findings from the present study depicting overall error consistency as a moderately strong predictor are worthy of future examination and possible clinical application.

Acknowledgments

This article is based, in part, on the third author’s master’s thesis completed in May 2000 at the University of Nevada, Reno. This research was supported in part by a grant from the National Institute on Deafness and Other Communication Disorders to the University of Nevada, Reno (DC03358). We also wish to express our thanks to the children, their parents, and the Washoe County School District SLPs and teachers who participated in this research.

References


### Appendix

**Phonological Goals for Each Participant**

<table>
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<tr>
<th>Participant</th>
<th>Initial Study Phonology Goals</th>
<th>Replication Study Phonology Goals</th>
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**Note.**  
A = simultaneous first; B = alternating first; C = phonology first; D = morphosyntax first.  
*Intervention target during individual sessions.