# Examining Speech Production in 3- and 4-Year-Old Typically Developing Children:

# A Comparison Study for the American English Phrase Sample

by

Hannah F. McNeal

A Thesis Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Science

Approved April 2024 by the
Graduate Supervisory Committee:

Nancy J. Scherer, Chair
Laurel Bruce
Kelly N. Cordero
Jessica L. Williams

ARIZONA STATE UNIVERSITY

May 2024

ABSTRACT

The standard of care by multiple cleft teams includes utilizing controlled speech samples, such as the American English Phrase Sample (AEPS), which is controlled for each sound class in different word positions to rate cleft speech characteristics, mainly resonance, within multi-word contexts. This study aimed to provide information on traditional speech errors and speech sound accuracy in typically developing (TD) children aged three to four years on this phrase repetition task. Additionally, it compared speech sound accuracy between single-word articulation and phrases. Finally, the speech samples from a small group of non-cleft children with a speech delay were described in relation to their TD peers.

Thirty typically developing children without cleft palate and seven children with speech delays, ranging in age from 3-4;11 years old, were recruited from a larger study. The Sounds-in-Words subtest of the Goldman-Fristoe Test of Articulation-3rd Edition (GFTA-3) and the AEPS were administered. The GFTA-3 and AEPS were analyzed for traditional speech errors, Percent Consonants Correct (PCC) total and PCC by manner. Additionally, phonological processes were examined using the Khan-Lewis Phonological Analysis-3rd Edition (KLPA-3). Analysis of variance (ANOVA) and effect sizes were computed for the Substitutions, Omissions, Distortions, and Additions (SODA) and PCC comparisons of the children with typical development. The data for the children with speech delays are presented descriptively due to the small numbers.

Results revealed significant decreases in PCC for certain categories at the phrase level for 3-year-olds, with little variation in PCC for 4-year-olds. Children with speech delays exhibited lower PCCs for multiple manner classes compared to their TD peers.

Age showed significance in increased PCC for 4-year-olds. Substitution errors were prevalent in TD children, while children with speech delays demonstrated various error types. Error reduction correlated with increased age and varied by word position. Patterns differed between TD and speech delay groups across linguistic contexts.

Though originally intended to assess cleft palate speech characteristics, normative data on the AEPS helps contextualize speech characteristics observed within typical development. The current study addresses the lack of normative data on the AEPS for comparison to children with cleft palate with or without cleft lip (CP+/-L). Additionally, it provides normative data for PCC and PCC by manner at the single-word and phrase level. Overall, the results of this study support the claim that children perform similarly on the AEPS as the GFTA-3, with a few variations depending on context.

ACKNOWLEDGMENTS

I would first like to extend a special thank you to the committee chair, Dr. Nancy Scherer, for her unwavering support, guidance and patience at every stage of my thesis journey. I would like to extend a sincere thank you to the members of the Graduate Supervisory Committee: Dr. Laurel Bruce, Dr. Kelly Cordero, and Jessica Williams, for their guidance and support throughout the thesis experience. I would like to thank Jillian Kuo who assisted me in collecting speech samples at ASU's Child Development Lab. I would also like to extend a thank you to Natalie Wombacher who provided her expertise in coding for data analysis and assisted with final consensus ratings for the speech samples. Additionally, I would like to thank Madi Pettijohn who completed a few last-minute consensus ratings as well. Thank you to the children and their families for their willingness to participate in this study. Finally, I would like to thank my family and friends, especially my mom, for their support and encouragement throughout my thesis journey

TABLE OF CONTENTS

APPENDIX Page

LIST OF TABLES

LIST OF FIGURES

Figure Page

# CHAPTER 1

# INTRODUCTION

Speech sound disorders are among the most common types of pediatric communication disorders. They are categorized as either functional (i.e., articulation or phonological disorders) or organic (i.e., motor/neurological, structural, sensory/perceptual) (American Speech-Language-Hearing Association, n.d.). Articulation and phonological disorders use different classification systems. Articulatory descriptions assess errors related to developmental maturation, which are frequently categorized into substitution, omission, distortion, and addition (SODA) errors. In contrast, phonological descriptions assess speech errors according to phonological rules that are evolving during early development. Both systems provide information about the child's speech acquisition, one more focused on placement and the other focused on language rules that govern phonological learning.

The Americleft Speech Protocol comprises of a variety of speech tasks, including a controlled sentence imitation task, which is widely used as the standard of care by multiple cleft teams in the U.S. (Trost-Cardamone, 2012; Chapman et al., 2016). The sentences were developed for 5–7-year-old children and subsequently a phrase task was developed for children 3-5 years of age. The purpose of the sentences and phrases is to collect a sample of controlled speech for each sound class in different word positions in order to assess cleft palate speech characteristics, such as hypernasality, audible nasal air emission, and hyponasality, in addition to developmental speech sound errors and cleft-related errors (e.g., glottal stop substitutions, nasal emission). The sentences and phrases are used to assess articulation and resonance in children with cleft palate who may require speech therapy and/or secondary surgical management. The three-to-seven-year age range is the critical period in which most surgical decisions are made for secondary palate surgery (Sitzman et al., 2015; Pitkänen et al., 2022). Several studies have been completed using the American English Sentence Sample (Chapman et al., 2016; Lien, 2023). However, the phrases have not been normed on a comparison group of non-cleft children with typical development. Though the intent of these sentences and phrases is to assess cleft palate speech characteristics, it is important to have normative data on these phrases to ensure speech characteristics are also judged in the context of typical development and not only in the context of a cleft condition.

One study found that the frequency of errors children produced varied across speech contexts (e.g., word naming, sentence repetition, narrative retelling, and conversational speech) (Klintö et al., 2011). Among children with cleft palate, sentence repetition had just as high reliability and validity for assessing connected speech as narrative retell and conversational speech. In contrast, speech context did not appear to affect speech accuracy in the non-cleft children (Klintö et al., 2011). This study compared articulation performance in a phrase repetition task with single-word productions.

# CHAPTER 2

# LITERATURE REVIEW

## *Cleft Speech Errors*

Speech sound errors related to a cleft are broadly classified into two categories: obligatory and compensatory (Nikhila & Prasad, 2017; Chacon et al., 2017). Obligatory errors occur due to structural deficits and require surgical and/or prosthetic interventions to resolve. In contrast, compensatory errors are believed to be learned and habituated when a child attempts to compensate for their structural deficiencies. Compensatory errors may also be due to inability to generate and/or maintain sufficient intraoral pressure necessary for production of most consonant sounds (Nikhila & Prasad, 2017; Chacon et al. 2017). These errors may persist following surgical management. Additionally, children with a cleft palate are at high risk for phonological errors persisting beyond the typical age of elimination due to decreased hearing status resulting from frequent middle-ear infections, as well as delayed language development (Nikhila & Prasad, 2017; Chacon et al. 2017).

John et al. (2006) grouped cleft-related errors in relation to structure and function, which were also referenced in the Americleft speech project (Chapman et al., 2016) and expanded upon by Lien et. al (2023) to include anterior oral speech errors, posterior oral speech errors, non-oral compensatory errors, passive speech errors, ingressive articulation errors, and phonological nasal substitutions (See Appendix B for examples). Anterior oral errors include dentalization, lateralization, palatalization, mid-dorsum palatal production, bilabial fricatives, and reversed labiodental placement. Posterior oral errors include double articulation (alveolar with velar production) and productions that are backed to velar or uvular articulatory placement. Non-oral compensatory speech errors include glottal and pharyngeal articulatory productions. Passive speech errors include weakened or nasalized consonants, nasal realizations of stops and fricatives, and gliding of fricatives or affricates. Ingressive errors involve ingressive oral or nasal fricatives and non-pulmonic clicks. Phonological nasal substitutions are nasal substitutions that are not judged to be occurring secondary to velopharyngeal insufficiency.

In the recent study conducted by Lien et al. (2023), of the cleft-related errors, the most prevalent were anterior oral speech errors, followed by non-oral compensatory errors. Though these errors are often associated with velopharyngeal and palatal fistulae, some do occur occasionally in typically developing (TD) children. While this study focuses on typical articulation and phonologic performance on single words and phrases, this data serves as a non-cleft comparison to a group of children with CP±L for future studies and for clinical application. Additionally, the data were evaluated for common cleft-related speech errors.

***Articulation Errors***

Articulation disorders are characterized by difficulty in either accurately producing or distorting age-appropriate speech sounds. A SODA (substitution, omission, distortion, addition) analysis is often performed to examine articulation errors. Substitutions are when one or more sounds are replaced by another (e.g, /pɪg/ → /pɪk/). Omissions are sounds that are omitted or deleted (e.g., /θʌm/ → /ʌm/). Distortions are productions that are recognized as the target phoneme but are acoustically inaccurate (e.g., lateralized /s/). Additions are extra sounds that are added (e.g., adding a schwa “puh-late”). The Goldman-Fristoe Test of Articulation – Third Edition (GFTA-3;

Goldman & Fristoe, 2015) is a widely-used standardized measure for clinical assessment of articulation and is used to guide treatment planning. Children are asked to produce 60 target words in a picture book that elicits articulation of consonants and consonant clusters. Normalized data are controlled for both age and gender.

Regarding typical speech development, the cross-linguistic review by McLeod and Crowe (2018) found a steady increase in consonant acquisition, with four consonants, /ɹ, ʒ, ð, θ/, being acquired last. In a subsequent study, Crowe and McLeod (2020) found similar results when reviewing consonant acquisition specifically in children living in the United States. Using 90% criterion, all stops, nasals, and glides are typically acquired by 3:11; all affricates by 4:11; all liquids by 5:11; and all fricatives by 6:11.

All toddlers produce what are considered typical speech errors. However, toddlers with speech sound disorders (SSDs) produce atypical errors or typical errors that have not resolved by the expected developmental timeline. Atypical errors refer to omissions, substitutions, syllable structure errors, and distortions that are rarely found in typical phonological development (To et al., 2022). Their speech is often characterized by higher rates of omissions and presence of atypical speech errors, such as initial consonant omission (e.g., /ʃu/ → /u/) and backing of alveolars (e.g., /pɪg/ → / kɪg/) (To et al., 2022; Brosseau-Lapre & Roepke, 2019; Preston & Edwards, 2010). Additionally, they may exhibit glottal replacements of oral consonants, and fricative substitutions for stop consonants (Preston & Edwards, 2013).

***Developmental Phonological Errors***

Systematic error patterns of speech, also known as phonological processes, have been well-documented in literature (Dodd et al., 2003; Bernthal et al., 2022).

Phonological processes are rule-governed simplifications of adult models commonly produced by young children and have a generally predictable timeline of elimination. These patterns are categorized as typical developmental patterns or atypical developmental patterns based on the prevalence of each observed in the general population. If these errors persist past the expected age of elimination, further assessment of speech and language abilities is indicated to determine the presence or absence of a speech sound disorder. In a study examining the speech errors in children ages 4:0-7:11 with cleft palate with or without cleft lip (CP±L), Lien et al. (2023) found that developmental/phonological errors were more frequent than cleft-related errors; however, the frequency of each phonological process was not reported. The current study describes developmental/phonological errors based on the frequency of occurrence.

Regarding the types of phonological processes present in typical development, Dodd et al.'s (2003) study of 684 mono-lingual English speaking children between 3;0 and 6;11 years of age, found that error patterns decreased with age, where voicing (/dʌk/ → /dʌg/), stopping (/ʃʌvəl/ → /ʃʌbəl/), weak syllable deletion (e.g. /ɛləfənt/ → /əfənt/), and fronting (e.g., /kʌp/ → /tʌp/) were resolved by 4;0. A subsequent study by Ceron et al. (2017) with 866 children aged 3;0-8;11 examined the prevalence of phonological disorders and phonological processes. They found cluster reduction to be the most common phonological process present in all age groups (Ceron et al., 2017). The majority of phonological processes have been reported to resolve rapidly between 2;5 and 4;0 years of age (Roberts et al., 1990; Dodd et al., 2003). Children with speech sound disorders lose their phonological processes at a slower rate than typically developing children (Stoel-Gammon, 1985; Gierut & Morrisette, 2012).

### *Speech Delays*

Speech delays are characterized by production of speech errors inappropriate for a child's age. Approximately 15% of 3-year-old children are diagnosed with a speech delay, which decreases to 3.8% by the time children are about 6 years of age. (Campbell et al., 2003; Shriberg et al., 1999). The decrease over time can be attributed to children resolving their speech through maturation. Studies have shown that the type of speech errors children are making may predict the likelihood of resolution, where children who were identified as making errors that were similar to younger children are more likely to resolve compared to children who are making atypical errors (Morgan et al., 2017; Dodd et al., 2018). Therefore, most children with speech delays will exhibit independent recovery and catch up with their peers, while the rest will need intervention. Wolk and Meisler (1998) highlight the importance of examining a child's disability at the level where the difficulty arises. When assessing children in clinical contexts, a comprehensive assessment is essential, and it is important to get a variety of speech performance in different contexts to examine functional speech sound abilities.

The first purpose of this study was to provide an analysis of the traditional speech errors and phonological errors that are usually produced by typically developing children ages 3;0-3;11 and 4;0-4;11 on the American English Phrase Sample (AEPS; See Appendix C). The second purpose was to compare speech sound accuracy between single-word articulation and the phrase sample. Finally, the error types produced by a small group of non-cleft children with a speech delay were described in relation to typically developing errors.

**Research Questions**

1. What are the characteristics of articulation error types (i.e., substitutions, omissions, distortions, additions) in different word positions (i.e., initial, medial, final) among the typically developing children and children with speech delays for 3-3;11 and 4-4;11-year-olds?
2. Among the typically developing children and children with speech delays, is there a difference in the percent of consonants correct (PCC) and PCC by manner between single-word and short phrase production?
3. What are the types and frequency of phonological processes being produced among the typically developing children and children with speech delays for 3-3;11 and 4-4;11-year-olds?

CHAPTER 3

# METHODOLOGY

This study received institutional review board approval from Arizona State University (See Appendix A). Informed consent procedures were conducted with parents prior to collecting the speech samples.

## Participants

Participants were recruited as part of a larger study of 3-4:11 year-olds with and without cleft palate. The children were recruited through local daycare and preschool centers, flyers distributed throughout the ASU campus, and word-of-mouth Thirty-seven children between ages 36 and 59 months (mean age = 48.32 months) from the larger study were used in the current study. Of the thirty-seven children, seven were revealed to be below the $10^{th}$ percentile in speech production abilities, based on results of a standardized articulation assessment. This corresponds with a standard score of ≤80. All participants completed the assessment protocols in English. Table 1 shows the number of children whose speech samples have been collected by age, sex, and GFTA-3 percentiles above and below the 10th percentile. Figure 1 show the demographics of the participants, including age, sex, ethnicity/race, and maternal education.

**Table 1**

*Participant Demographics*

| Characteristic | Typically-Developing | | Children with Speech Delays | |
|---|---|---|---|---|
| | **n** | **%** | **n** | **%** |
| **Age** | | | | |
| 3:0-3:11 | 15 | 50% | 3 | 42.9% |
| 4:0-4:11 | 15 | 50% | 4 | 57.1% |
| **Sex** | | | | |
| Male | 18 | 60% | 2 | 28.6% |
| Female | 12 | 40% | 5 | 71.4% |
| **Ethnicity/Race** | | | | |
| White/Caucasian | 21 | 57% | 3 | 43% |
| Black/African American | 0 | 0% | 0 | 0% |
| Hispanic/Latino | 0 | 0% | 0 | 0% |
| Asian | 3 | 8% | 0 | 0% |
| Hawaiian/Pacific Islander | 0 | 0% | 0 | 0% |
| Native American or Alaska Native | 0 | 0% | 0 | 0% |
| 2 or more | 6 | 16% | 4 | 57% |
| **Maternal Education** | | | | |
| High School/GED | 0 | 0% | 0 | 0% |
| Some College | 1 | 3.3% | 1 | 14.3% |
| Community College | 1 | 3.3% | 0 | 0% |
| BS/BA | 8 | 26.7% | 2 | 28.6% |
| Graduate School | 0 | 0% | 1 | 14.3% |
| Graduate Degree | 13 | 43.3% | 1 | 14.3% |
| PhD | 7 | 23.3% | 2 | 28.6% |

## Materials

### *Single-Word Articulation*

The Goldman-Fristoe Test of Articulation – Third Edition (GFTA-3) Sounds-in-Words subtest was administered (Goldman & Fristoe, 2015). The GFTA-3 is a valid and reliable standardized assessment of articulation abilities in children as young as two years of age. The subtest consists of 60 words for the child to produce and is used to assess all English phonemes in different word positions, as well as consonant clusters.

### ***Phonological Analysis***

The Khan-Lewis Phonological Analysis – Third Edition (KLPA-3; Khan & Lewis, 2015) was used to determine the type and frequency of phonological processes produced by the two typically developing (TD) age groups, as well as the small group of children with speech delays. The KLPA-3 is a norm-referenced analysis of developmental and phonological processes using the responses obtained from the GFTA-3. The frequency of 12 core developmental/phonological processes commonly produced by young children are identified and grouped into four types of processes (manner, place, reduction, and voicing processes). Manner processes include deaffrication, gliding of liquids, stopping of fricatives and affricates, stridency deletion, and vocalization. Place processes include palatal fronting and velar fronting. Reduction processes include cluster simplification, deletion of final consonant, and syllable reduction. Voicing processes include final devoicing and initial voicing.

### ***Phrase Repetition Task***

The American English Phrase Sample (AEPS; Chapman et al., 2016) was administered. The AEPS consists of 24 short phrases and was adapted from the American English Sentence Sample for children between 3-5 years of age (Trost-Cardamone, 2012). The sentences and phrases were created as a controlled sample to assess cleft palate speech characteristics, such as hypernasality, audible nasal air emission, and hyponasality, in addition to speech sound errors and cleft-related errors. They were designed according to Henningsson et al. (2008) universal speech parameters by (1) sampling all oral pressure consonants, (2) limiting each utterance to one target consonant, (3) controlling for high and low vowels, and (4) excluding nasal phonemes. Nasal phonemes were assessed separately from the oral pressure phonemes. Each phrase is loaded with a specific target sound in the initial and final word positions. Sound errors were transcribed and total errors were calculated for the phrases. Total PCC and PCC by manner of production were determined from the phrases for total PCC and PCC by manner of production.

**Procedures**

The speech samples were video recorded using a Zoom Q8 handy Video Recorder and an Audio-Technica Short-Shotgun Microphone on a boom stand. Audio recordings were deidentified, assigned a participant ID and subsequently uploaded to Dropbox.

***Missing data***

During coding, data was marked as missing and excluded from subsequent analysis if the target word or phrase was not obtained during testing.

***Transcription and Analysis of GFTA-3 and KLPA-3***

The speech samples were phonetically transcribed using the International Phonetic Alphabet (IPA 2015). A raw error score was obtained and converted to a standard score and percentile rank. The errors were further analyzed using GFTA-3 Sounds-in-Words Phonetic Error Analysis and the KLPA-3. The Phonetic Error Analysis provides a non-standardized measure for analysis of speech sound abilities. Errors were coded into an Excel workbook and categorized into four main types (substitutions, omissions, distortions, and additions), as well as word position (initial, medial, final).

The KLPA-3 was completed for each child using results from the GFTA-3 and a standard score, percentile rank, and frequency of occurrences of each phonological process were obtained. The type and frequency of each phonological process was coded into an Excel workbook for statistical analysis for the TD children. While not included in the calculation for the standard score and percentile rank, the occurrence of supplemental and other phonological processes on the KLPA-3 were determined. This procedure was used to analyze the results of the children with speech delays but a descriptive analysis, rather than a statistical one was reported.

***Analysis of Speech Sound Accuracy***

The percentage of consonants correct (PCC) and PCC by manner of production were calculated for both the GFTA-3 and the AEPS (Shriberg et al., 1997; Shriberg & Kwiatkowski, 1982). PCC is a relational analysis measure, where a child's productions are compared to adult target productions. It is calculated by subtracting the total number of consonants evaluated on each assessment (141 items on the GFTA-3 and 39 items on the AEPS) by the raw score (i.e., total number of errors) to determine the number of consonants produced correctly. This number is then divided by the total number of items assessed to calculate the PCC. To calculate PCC and PCC by manner, consonants were coded as accurate or inaccurate using the three types of error analyses (i.e., SODA, phonological processes, and cleft-related errors) on an Excel workbook. These procedures were used for all comparison groups, but a descriptive analysis was used to report the data for the children with speech delays, while a statistical analysis was performed for the TD children.

**Transcription Agreement.** Inter-rater reliability was conducted to ensure the accuracy of the transcriptions of the GFTA-3 and the American English Phrase Sample on 20% of the sample (n=7). Two raters separately transcribed the assigned samples. A point-by-point agreement was conducted. When a discrepancy was found, the recording was played again until a consensus was reached. If consensus was not reached between the two raters, a third rater was used to help reach consensus. The primary raters were the author of this thesis (H.M.) and a certified speech-language pathologist (N.S.) with extensive experience in phonetic transcription. The two consensus raters were another certified speech-language pathologist (SLP) and a graduate student trained in transcription. To calculate inter-rater reliability, the total number of agreements was divided by the total number of agreements and disagreements, and this quotient was multiplied by 100. Inter-rater agreement for the GFTA-3 was 94% and was 93% for the AEPS between the first author and the SLP (N.S.).

**Coding Reliability for SODA and KLPA-3.** The same transcription raters were used for coding reliability of 20% of the samples to ensure the accuracy of the categorization of the type of speech errors, and type and frequency of phonological processes present in the sample. Coding was conducted after transcription agreement was reached. Similarly, two raters separately coded the speech errors and phonological processes. When a discrepancy was found and consensus could not be reached between the two coders, a third coder was used to help reach consensus. The inter-rater agreement for the SODA analysis was 100% and for the KLPA-3 was 98% between the first author and the SLP (N.S.)

### *Statistical and Descriptive Analysis*

An analysis of variance (ANOVA) was conducted to address the research questions and was used to determine whether there was a statistically significant difference. Due to the small sample of seven children identified as having a speech delay, descriptive analysis was conducted to examine their errors.

*Calculating Effect Sizes*

Effect sizes were calculated using the F-test statistic results and eta squared ($\eta^2$). Eta squared was calculated by dividing the sum of squares of the treatment divided by the total sum of squares. Effect size is classified as negligible (<.01), small (<.06), medium (<.14), and large (>.14).

# CHAPTER 4

# RESULTS

The results will be presented for each research question and broken down into the specific analyses conducted. For the first research question, total SODA errors will be presented first for both the GFTA-3 and AEPS between the two age groups, then results will be presented for the GFTA-3 first, followed by results for the AEPS. Please note, the comparisons between the GFTA-3 and AEPS for the SODA error analyses were not reported due to the disproportionate number of opportunities on the GFTA-3 (total of 141 opportunities) compared to the AEPS (total of 39 opportunities). The second research question talks about total PCC for the GFTA-3 and AEPS. PCC by Manner will then be presented between the GFTA-3 and AEPS. Finally, the top ten developmental/phonological processes present in the typically developing (TD) children and children with speech delays will be discussed.

## Research Question 1: Traditional Speech Errors (SODA)

What are the characteristics of articulation error types (i.e., substitutions, omissions, distortions, additions) in different word positions (i.e., initial, medial, final) among the TD children and children with speech delays for 3-3;11 and 4-4;11-year-olds?

### *Total SODA Errors in the GFTA-3 and AEPS*

The speech samples of the two TD groups were analyzed by calculating the total speech errors between the two ages on the Goldman-Fristoe Test of Articulation-Third Edition (GFTA-3) and the American English Phrase Sample (AEPS). To determine whether there was a statistically significant difference between the 3- and 4-year-old group on both measures, an ANOVA was conducted. Figure 1 presents the total SODA errors in the single-word articulation task (GFTA-3) and phrase repetition task (AEPS) between the TD children and children with speech delays. A statistically significant decrease in total mean speech errors at the single-word level was observed between the 3 and 4-year-old group (F (1, 28) = 10.06, $p = .003$, $\eta^2 = .26$). Specifically, the mean total speech errors at the single-word level for the 3-year-old TD children was 32.80 (SD=17.60), decreasing to 16.27 (SD=9.89) for the 4-year-old TD children. The effect size for the total mean speech errors at the word level between the two TD age groups was large.

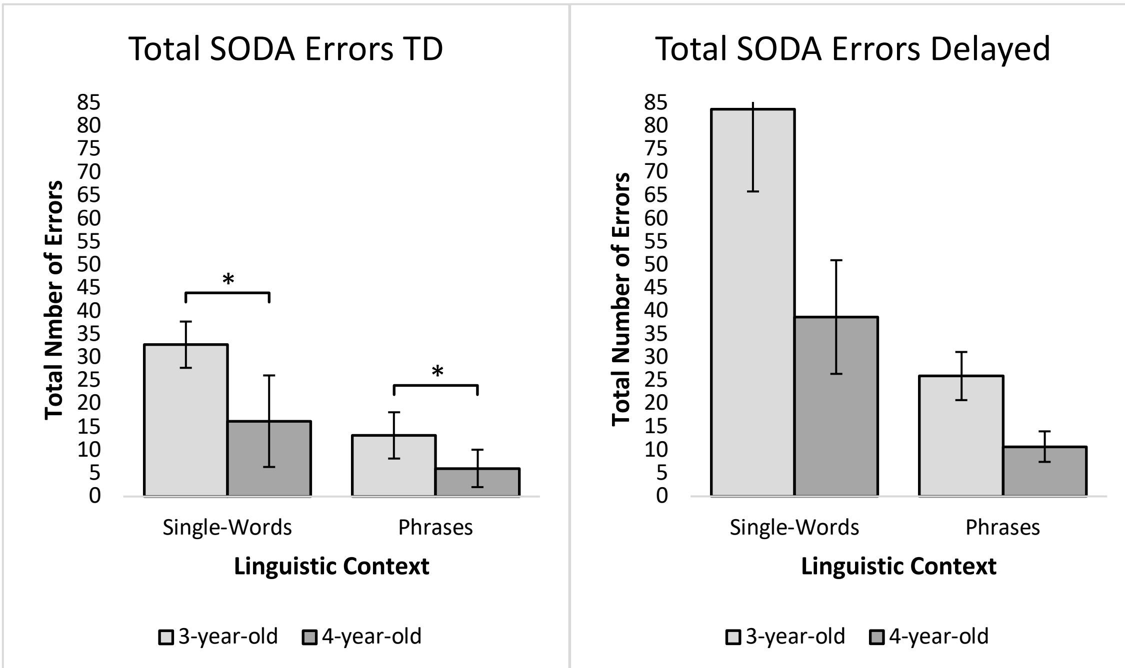
Similarly, a statistically significant decrease was found in total speech errors between the two TD age groups on the AEPS (F (1, 28) = 17.2, $p = <.001$, $\eta^2 = .38$). The mean total speech errors at the phrase level for the 3-year-old TD children decreased from 13.2 (SD=5.29) to 6.07 (SD=4.04) in the 4-year-old children. The effect size for the total mean speech errors at the phrase level between the two TD age group was large.

Descriptive statistics were performed to provide means and standard deviations for total traditional speech errors (SODA) between the two ages on both the GFTA-3 and AEPS for the small group of 3- and 4-year-old children with speech delays, as depicted below in Figure 1. At the single-word level, the mean total speech for the 3-year-old children with speech delays were distinctly higher at 83.67 (SD=17.79), while for the 4-year-old children, it reduced to 38.75 (SD=12.28).

A similar pattern as observed in the TD group emerged on the AEPS for the children with speech delays. For the 3-year-old children with speech delays, the mean total speech errors was 26.00 (SD=5.20), whereas for the 4-year-old children with speech delays, it decreased to 10.75 (SD=3.30).

**Figure 1**

*Total errors in single words and phrases*




Note. * denotes p = <.05

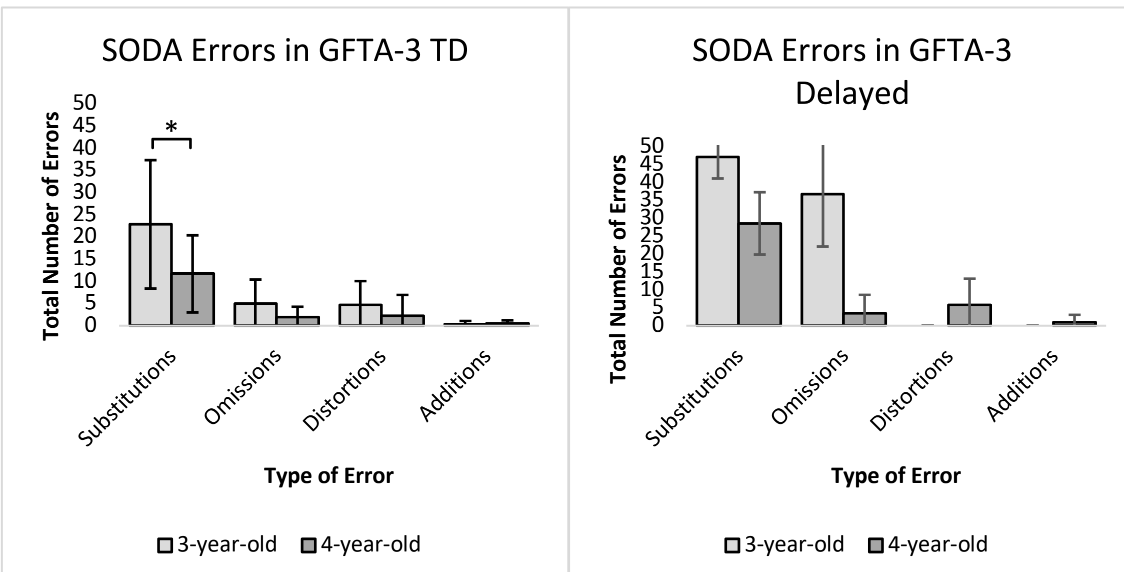
***Type of Speech Errors in the GFTA-3***

Speech errors were examined by the types of traditional speech errors (SODA) produced during the GFTA-3 using an ANOVA. Figure 2 presents the total substitution, omission, distortion, and addition errors at the single-word level for the TD children and children with speech delays. In the single-word articulation task, only substitution errors were statistically significantly different between the 3- and 4-year-old children ($F$ (1, 28) = 6.53, $p$ = .02, $\eta^2$ =.18), whereas omission ($F$ (1, 28) = 4.14, $p$ = .05, $\eta^2$ = .12), distortion ($F$ (1, 28) = 1.79, $p$ = .19, $\eta^2$ = .06), and addition ($F$ (1, 28) = 0.25, $p$ = .62, $\eta^2$ = .008) errors were not found to be statistically significantly different. Distortion errors were characterized by dentalization or lateralization of /s, z/, or nasalization. A significant reduction was observed for substitution errors in the 4-year-old TD children. The mean total substitution errors for the 3-year-old TD children was 22.80 (SD=14.47), decreasing to 11.67 (SD=8.68) in the 4-year-old children. The mean total omission errors for the 3-year-old TD children was 5.00 (SD=5.36), while the mean was 1.93 (SD=2.31) for the 4-year-old TD children. The mean total distortion errors for the 3-year-old TD children was 4.67 (SD=5.37), while the mean total distortion errors for the 4-year-old TD children was 2.20 (SD=4.71). Finally, the mean total addition errors for the TD 3-year-old children was 0.33 (SD=0.72), whereas the 4-year-old TD children had a mean of 0.47 (SD=0.74). There was a large effect size for the substitution errors between the two TD age groups. While there was no statistical significance found for the other types of errors, there were medium effect sizes for omission and distortion errors. The effect size was negligible for addition errors.

In the analysis of the types of traditional speech errors (SODA) in the GFTA-3 for the small group of 3- and 4-year-old children with speech delays, means and standard deviations are provided using descriptive statistics. The children with speech delays demonstrated a high number of substitutions and omissions compared to the TD groups and 4-year-old children with speech delays. The mean total substitution errors for the 3-year-old children with speech delays decreased from 47.00 (SD=6.00) to 28.50 (SD=8.70) for the 4-year-old children with speech delays. Additionally, the mean total omission errors decreased from 36.67 (SD=14.64) in the 3-year-old children with speech delays to 3.50 (SD=5.07) in the 4-year-old children with speech delays. In contrast to the decrease observed for substitution and omission errors, an increase was observed in distortion and addition errors in the 4-year-old children with speech delays. The mean total distortion errors for the 3-year-old children with speech delays was 0.67 (SD=0.58), increasing to 5.75 (SD=7.32) in the 4-year-old children with speech delays. The mean total addition errors for the 3-year-old children increased from 0.00 (SD=0.00) to 1.00 (SD=2.00).

**Figure 2**

*Total errors by type in the GFTA-3*




Note. * denotes p = <0.05.

### *SODA Errors by Word Position in the GFTA-3*

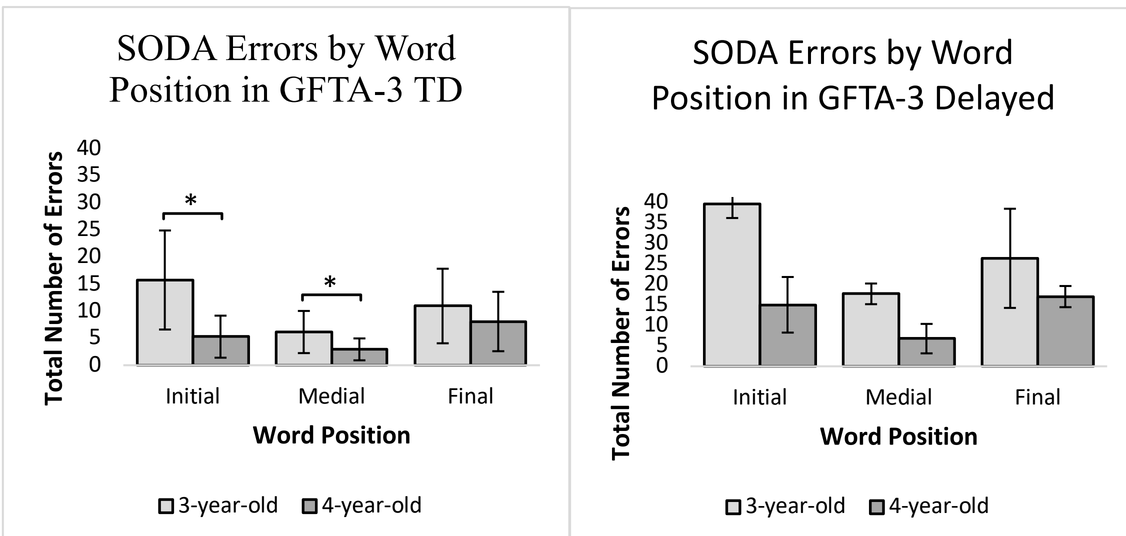
To examine the traditional speech errors (SODA) closer, the speech samples were analyzed by word position in the GFTA-3 using an ANOVA. Figure 3 illustrates the total SODA errors at the single-word level across different word positions for both 3- and 4-year-old TD children and children with speech delays. Statistically significant differences and large effect sizes were observed in total speech errors for the 3- and 4-year-old TD children during the single-word articulation task across various word positions, including the initial (F (1, 28) = 16.67, *p* = <.001, $\eta^2$ = .37) and medial (F (1, 28) = 8, *p*=.009, $\eta^2$ = .22) position, between the two TD age groups. There was a significant reduction in total errors in the initial word position from age 3 to 4 years. For the 3-year-old TD children, the mean total speech errors in the initial position was 15.73 (SD=9.14), decreasing to 5.27 (SD=3.88) in the 4-year-old children. As seen for the initial position, there was a significant reduction in total errors in the medial position from age 3 to 4 years. The mean total speech errors in the medial position for the 3-year-old TD children was 6.13 (SD=3.89), in contrast to the 4-year-old TD children who had a lower mean of 2.93 (SD=2.02). There was a small reduction seen in the final position, where the 3-year-old TD children had a mean total speech errors of 10.93 (SD=6.88), compared to 8.07 (SD=5.48) for the 4-year-old TD children; however this difference was not statistically significant ((F (1, 28) = 1.59, *p* = .21, $\eta^2$ = .05) and had a small effect size.

To provide means and standard deviations, descriptive statistics were conducted to describe the types of traditional speech errors (SODA) by word position in the GFTA-3 for the small group of 3- and 4-year-old children with speech delays. A decrease was observed in the number of errors across all word positions (initial, medial, final) between the 3- and 4-year-old children with speech delays. The mean total speech errors in the initial position was 39.67 (SD=3.51) for the 3-year-old children with speech delays, decreasing by more than half in the 4-year-old children with speech delays with a mean of 15.00 (SD=6.78). A similar pattern was observed for the medial position. In the medial position, the mean total speech errors for the 3-year-old children with speech delays was

17.67 (SD=2.52), while it was 6.75 (SD=3.59) for the 4-year-old children with speech delays. A reduction in the number of errors was also observed in the final position with a mean of 26.33 (SD=12.09) for the 3-year-old children with speech delays to 17.00 (2.58) for the 4-year-old children with speech delays.

**Figure 3**

*Total errors by word position in the GFTA-3*




Note. * denotes p=<.05

***SODA Errors Between Word Positions in the GFTA-3***

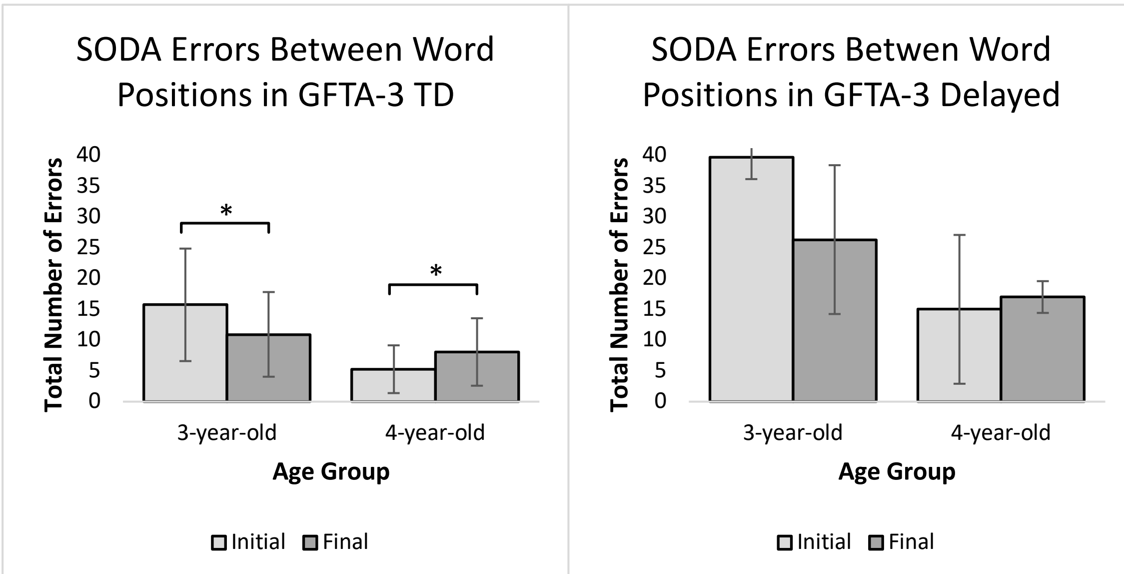
The total SODA errors were compared between the initial and final position for both the TD age groups in the GFTA-3. Figure 4 illustrates the total SODA errors at the single-word level between word positions for the 3- and 4-year-old TD children and children with speech delays. For the 3-year-old TD children, there was found to be a statistically significantly decrease in total errors between the initial and final position (F

(1, 14) = 5.91, $p$ = .03, $\eta^2$ = .08). In the 3-year-old TD children, the mean for the initial position was 15.73 (SD=9.14), whereas the mean for the final position was 10.93 (SD=6.88). In the 4-year-old TD children, there was found to be a statistically significant increase in total errors between the initial and final position (F (1, 14) = 5.44, $p$ = .035, $\eta^2$ = .08). In the 4-year-old TD children, the mean for the initial position was 5.27 (SD=3.88), increasing to 8.07 (SD=5.48) for the final position. When examining total errors between the initial to final position, there was a medium effect size for both the 3- and 4-year-old TD children.

For the small group of children with speech delays, descriptive statistics were calculated to provide means and standard deviations of the total SODA errors between the initial and final position in the GFTA-3. A similar pattern to the TD children was observed in the children with speech delays. The mean total speech errors was less in the final position for the 3-year-old children with speech delays. They had a mean of 39.67 (SD=3.51) in the initial position and 26.33 (SD=12.09) in the final position in the 3-year-old children with speech delays. In contrast, the mean total speech errors was higher in the final position of words with a mean of 17.00 (SD=2.58) and a mean of 15.00 (SD=6.78) in the initial position for the 4-year-old children with speech delays.

**Figure 4**

*Total errors between word positions in the GFTA-3*




Note. * denotes p=<.05

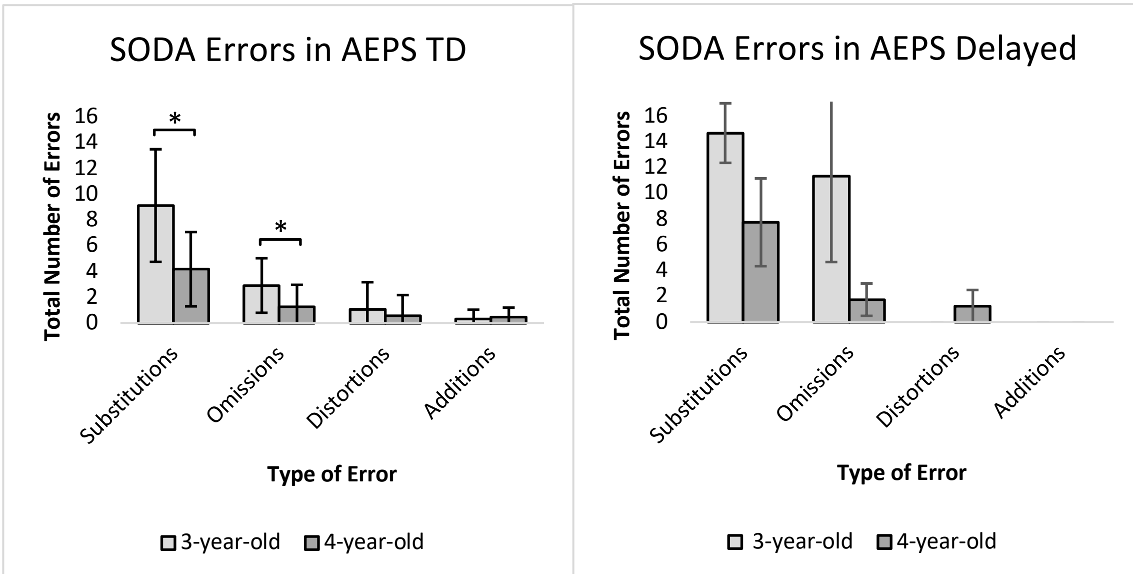
### *Type of Speech Errors in the AEPS*

Errors in the AEPS were examined by the types of traditional speech errors (SODA) using an ANOVA. Figure 5 presents the total substitution, omission, distortion, and addition errors at the phrase level for the TD children and children with speech delays. When examining the types of traditional speech errors (SODA) in the phrase repetition task, substitution ($F$ (1, 28) = 13.31, $p$=.001, $\eta^2$ = .32) and omission ($F$ (1, 28) = 5.62, $p$=.025, $\eta^2$ = .16) errors were statistically significantly different between the 3- and 4-year-old children, whereas distortion ($F$ (1, 28) = 0.46, $p$ = .50, $\eta^2$ = .01) and addition ($F$ (1, 28) = 0.25, $p$ = .62, $\eta^2$ = .008) errors were not found to be statistically significant. As in the single-word articulation task, distortion errors were characterized by dentalization or lateralization of /s, z/. No nasalization was noted for any of the age groups in the phrase repetition task. A significant reduction in substitution and omission errors was observed in the 4-year-old TD children. The mean total substitution errors for the 3-year-old TD children was 9.13 (SD=4.37), decreasing to 4.20 (SD=2.88) in the 4-year-old TD children. The mean total omission errors decreased from 2.93 (SD=2.12) in the 3-year-old TD children to 1.27 (SD=1.71) for the 4-year-old TD children. The mean total distortion errors for the 3-year-old TD children was 1.07 (SD=2.12), while the 4-year-old TD children had a mean of 0.60 (SD=1.59). The mean total addition errors for the 3-year-old TD children was 0.33 (SD=0.72), and was 0.47 (SD=0.74) for the 4-year-old TD children. In the phrase repetition task, substitution and omission errors between the two ages showed large effect sizes. Distortion errors showed a small effect size, while addition errors had a negligible effect size.

Descriptive statistics were calculated to provide means and standard deviations of the types of SODA errors for the group of children with speech delays. As demonstrated by the TD children, the 3-year-old children with speech delays had higher numbers of substitution and omissions than the 4-year-old children with speech delays. The mean total substitution errors for the 3-year-old children with speech delays was 14.67 (SD=2.31), which decreased to 7.75 (SD=3.40) in the 4-year-old children with speech delays. The mean total omission errors for the 3-year-old children was 11.33 (SD=6.66), decreasing to 1.75 (SD=1.26) in the 4-year-old children with. The 3-year-old children with speech delays did not demonstrate any distortions or additions at the phrase level. The mean total distortion errors for the 4-year-old children with speech delays was 1.25 (SD=1.25). No addition errors were observed in the 4-year-old children with speech delays.

**Figure 5**

*Total errors by type in the AEPS*




Note. * denotes p = <0.05

***SODA Errors by Word Position in the AEPS***

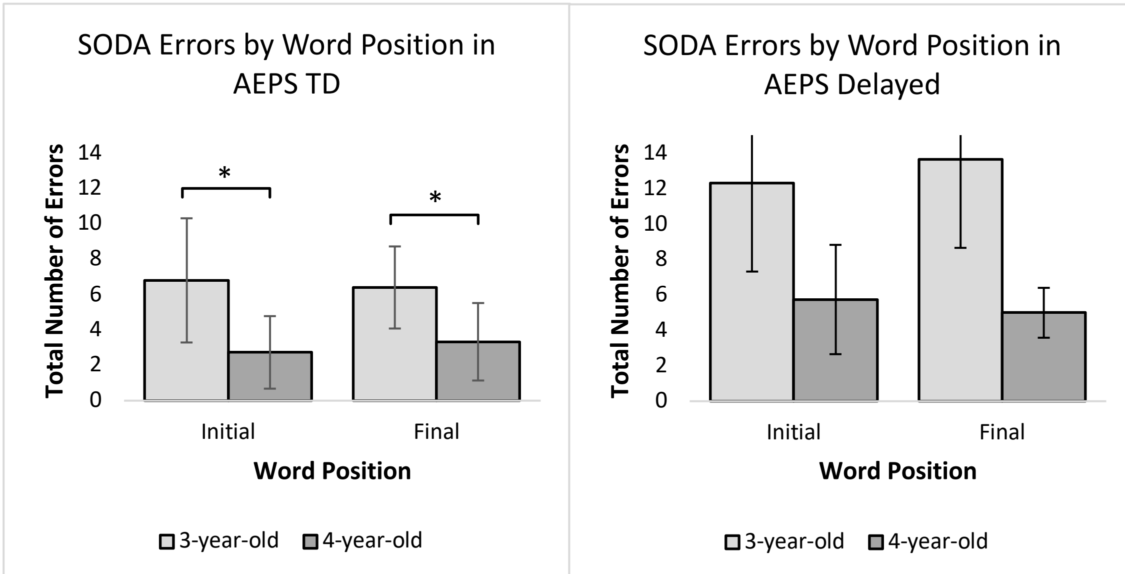
The total SODA errors for the AEPS were analyzed by word position using an ANOVA. Figure 6 presents the total SODA errors at the phrase level in the initial and final word positions for the 3- and 4-year-old TD children and children with speech delays. In the sample of TD children, total speech errors in the phrase repetition task in both the initial ($F(1, 28) = 15.01$, $p = <.001$, $\eta^2 = .34$) and final ($F(1, 28) = 13.82$, $p = <.001$, $\eta^2 = .33$) position were statistically significantly different between the two TD age groups. There was a significant reduction in total errors in the initial position for the 4-year-old children compared to the 3-year-old children. The mean total speech errors in the initial position for the 3-year-old TD children was 6.80 (SD=3.51), decreasing to 2.73

(SD=2.05) in the 4-year-old children. A significant reduction was also observed for the final position for the 4-year-old children. The mean total speech errors in the final position from 6.40 (SD=2.32) in the 3-year-old children to 3.33 (SD=2.19) in the 4-year-old children. Total speech errors in both the initial and final position showed large effect sizes.

The children with speech delays were analyzed using descriptive statistics to examine total SODA errors by word position in the AEPS. In the 4-year-old children with speech delays, the number of errors in both the initial and final position decreased by more than half. For the 3-year-old children with speech delays in the initial position, there was a mean of 12.33 (SD=2.52) and a mean of 5.75 (SD=3.09) in the 4-year-old children. In the final position, there was a mean of 13.67 (SD=3.51) for the 3-year-old children, while there was a mean of 5.00 (SD=1.41) for the 4-year-old children with speech delays.

**Figure 6**

*Total errors by word position in the AEPS*




Note. * denotes p = <0.05

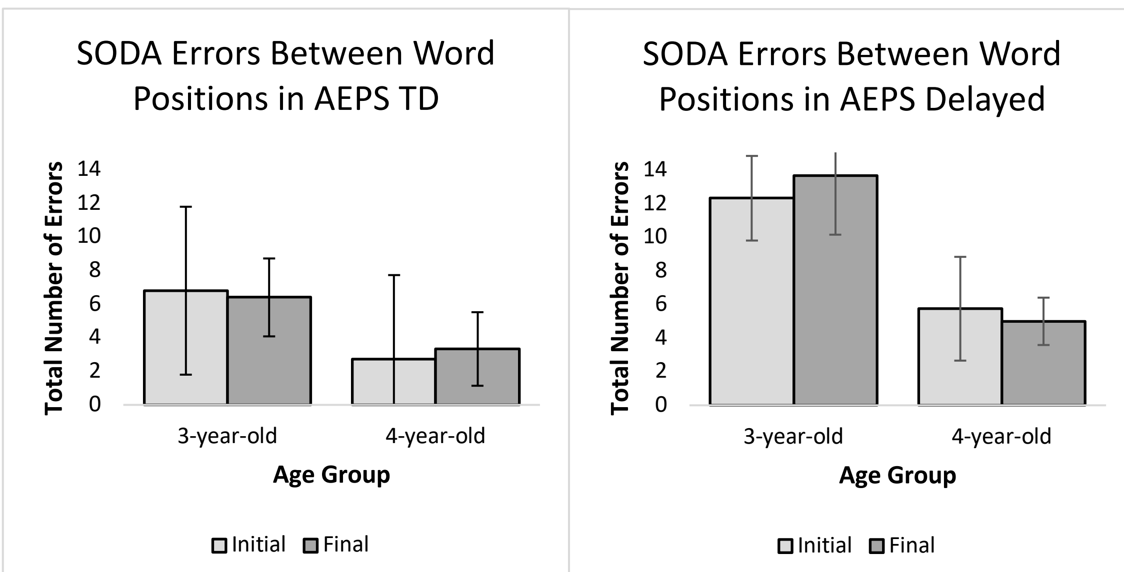
### *SODA Errors Between Word Positions in the AEPS*

The total SODA errors were compared between the initial versus final position for both the TD age groups for the AEPS. Figure 7 illustrates the total SODA errors at the phrase level between the two word positions for the 3- and 4-year-old TD children and children with speech delays. For the 3-year-old TD children, no statistically significantly difference was observed in total errors from the initial to final position (F (1, 14) = 0.32, $p$ = .58, $\eta^2$ = .40). Performance was similar for the 3-year-old children in both positions, with a mean of 6.80 (SD=3.51) in the initial position and a mean of 6.40 (SD=2.32) in the final position. For the 4-year-old TD children, no statistically significant difference was observed from the initial to final position (F (1, 14) = 3.2, $p$ = .095, $\eta^2$ = .02). The total number of errors were also similar in both positions for the 4-year-old TD children, with a mean of 2.73 (SD=2.05) in the initial position and a mean of 3.33 (SD=2.19) in the final position. In the 3-year-old children, there was a large effect size observed from initial to final position and a small effect size in the 4-year-old children.

Performance between the initial and final position was examined for the children with speech delays on the AEPS. The total number of errors was greater than in the TD children. For the 3-year-old children, the mean was 12.33 (SD=2.52) in the initial position and 13.67 (SD=3.51) in the final position. For the 4-year-old children, the mean was 5.75 (SD=3.09) in the initial position and 5.00 (SD=1.41) in the final position.

**Figure 7**

*Total errors between word position in the AEPS*




## Major Findings for Q1

- Substitution errors were the primary error type produced by the TD children.

- Addition errors were absent from the majority of all participants, regardless of the linguistic context (i.e., word and phrase level), age, or presence of a speech delay.
- The 3-year-old speech delay group produced a high number of substitution and omission errors, while the 4-year-old speech delay group had the highest number of distortion errors among all of the groups.
- In relation to word position, increased age was a determining factor in reduction of errors in each position, regardless of a speech delay.
- In both the GFTA-3 and AEPS, the 3-year-old TD children produced the most errors in initial, then final position, respectively, while the 4-year-old TD produced the most errors in final, followed by initial position, respectively.
- In the GFTA-3, the speech delay groups demonstrated a similar pattern as noted for the TD groups. However, in the AEPS, the 3-year-olds had the most errors in final and then initial position, while the 4-year-olds had the most in initial and then final position.

**Research Question 2: Percent of Consonants Correct (PCC)**

Among the TD children and children with speech delays, is there a difference in the percent of consonants correct (PCC) and PCC by manner between single-word and short phrase production?

***Total Percent of Consonants Correct in the GFTA-3 and AEPS***

Total PCC for the 3- and 4-year-old TD children in the GFTA-3 and AEPS was compared using an ANOVA. Figure 8 presents the total speech accuracy in the single-word articulation task and the phrase repetition task between the two age groups for the TD children and children with speech delays. When examining the total speech accuracy of the TD groups in the single-word articulation task, a statistically significant increase in total PCC was found between the two TD age groups ($F(1, 28) = 9.05$, $p=.006$, $\eta^2 = .22$). At the word-level, the mean PCC for the 3-year-old TD children was 78.73 (SD=12.04), increasing to 88.53 (SD=6.95) in the 4-year-old children. There was a large effect size between the two age groups for total PCC at the single-word level.

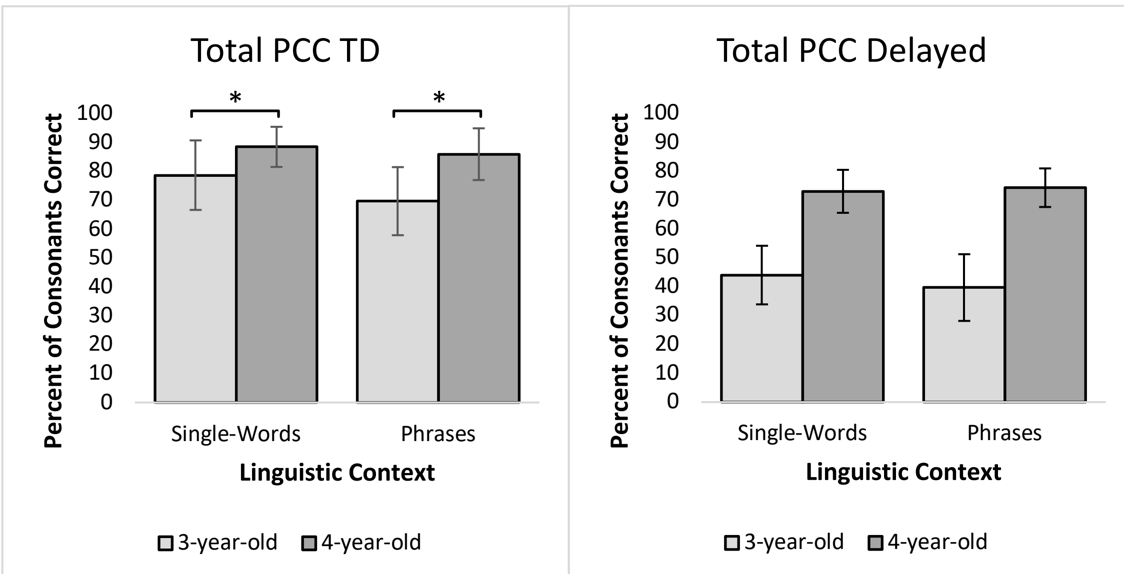
Similarly, the total speech accuracy in the phrase repetition task revealed a statistically significantly increase between the two TD age groups ($F(1, 28) = 18.09$, $p=<.001$, $\eta^2 = .38$). At the phrase level, the mean for the 3-year-old TD children was 69.73 (SD=11.79), which increased to 86.00 (SD=8.96) for the 4-year-old TD children. A large effect size for total PCC was observed at the phrase level.

Total PCC for the children with speech delays was examined in the GFTA-3 and AEPS using descriptive analysis. The accuracy in the single-word articulation task and phrase repetition task improved considerably in the 4-year-old children with speech delays compared to the 3-year-old children with speech delays. At the single-word level, the mean was 44.00 (SD=10.15) for the 3-year-old children with speech delays, increasing to 73.00 (SD=7.44) for the 4-year-old children with speech delays. At the phrase level, the mean was 39.67 (SD=11.55) for the 3-year-old children with speech delays, increasing to 74.25 (SD=6.68) for the 4-year-old children with speech delays.

Across the TD and speech delay groups, total PCC increased in the 4-year-old children. A significant increase was observed in total PCC in the GFTA-3 and AEPS. The children with speech delays also presented with an appreciable effect of total PCC between ages, where the 4-year-old children with speech delays had a higher PCC in the GFTA-3 and AEPS.

**Figure 8**

*Total PCC between ages in the GFTA-3 and AEPS*




Note. * denotes p = <0.05

***Total Percent of Consonants Correct between the GFTA-3 and AEPS***

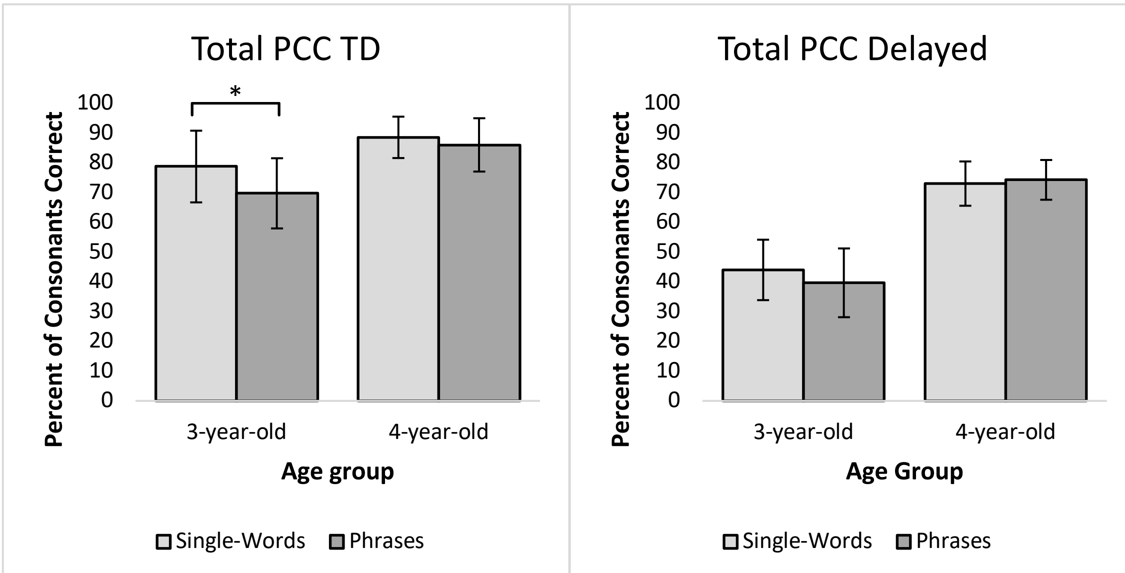
Total PCC was examined between the GFTA-3 and the AEPS for the TD children and children with speech delays. Figure 9 presents the total speech accuracy between the single-word articulation task vs the phrase repetition task for the two age groups for the TD children and children with speech delays. A statistically significant decrease in total PCC was observed in the 3-year-old children in the phrase repetition task compared to the single-word articulation task ($F$ (1, 14) = 14.12, $p$ = .002, $\eta^2$ = .10). No statistically significant difference was observed in the 4-year-old children between the single-word and phrase repetition task ($F$ (1, 14) = 3.56, $p$ = .08, $\eta^2$ = .08). In both age groups, medium effect sizes were evident when comparing the single-word articulation task to the phrase repetition task.

Total PCC was examined in the children with speech delays between the GFTA-3 and AEPS. Similar to the pattern seen in the TD children, speech accuracy was observed poorer at the phrase level compared to the single-word level for the 3-year-old children with speech delays. The 3-year-old children had a mean of 44.00 (SD=10.15) at the single-word level and a mean of 39.67 (SD=11.55) at the phrase level. However, speech accuracy for the single-word and phrase levels was similar in the 4-year-old children with speech delays. The 4-year-old children with speech delays had a mean of 73.00 (SD=7.44) at the single-word level and a mean of 74.25 (SD=6.68) at the phrase level.

When examining the speech accuracy between the GFTA-3 and AEPS, only the 3-year-old TD children showed a significant reduction in total PCC between the GFTA-3 and AEPS. However, the 4-year-old TD children performed similarly in both tasks. In the children with speech delays, the 3-year-old children demonstrated the lowest total PCC across all groups and linguistic contexts. Additionally, while only a descriptive observation can be made, the 4-year-old children with speech delays appeared to show the same pattern as the TD children, where they performed similarly in both tasks.

**Figure 9**

*Total PCC between linguistic contexts in the GFTA-3 and AEPS*




Note. * denotes p = <0.05

***Percent of Consonants Correct by Manner in the typically developing groups***

To examine PCC by manner for the 3- and 4-year-old TD children, an ANOVA was performed. Figure 10 presents PCC by Manner in the TD children between the GFTA-3 and AEPS. When examining PCC by Manner in the 3-year-old TD children, stops ($F$ (1, 14) = 13.38, $p$ = .002, $\eta^2$ = .29), fricatives ($F$ (1,14) = 14.68, $p$ = .001, $\eta^2$ = .13), and affricates ($F$ (1,14) = 11.44, $p$ = .004, $\eta^2$ = .10) were statistically significant. For stops, the mean speech accuracy was 90.60 (SD=6.41) in single-words, decreasing to 80.00 (SD=9.78) in phrases. For fricatives, the mean was 68.6 (SD=16.67) in single-words and was lower in phrases with a mean of 54.33 (SD=19.67). For affricates, the mean was 84.33 (SD=28.49) in single-words and was lower in phrases with a mean of 63.33 (SD=35.19).

No statistically significant difference was observed for nasals (F (1,14) = 0.88, $p$ = 0.364, $\eta^2 = .03$), liquids (F (1,14) = 0, $p = 1$, $\eta^2 = 0$), glides/glottal (F (1,14) = 1.76, $p$ = 0.2, $\eta^2 = .02$), or consonant clusters (F (1,14) = 0.08, $p = .78$, $\eta^2 = .001$). For nasals, the mean was 95.20 (SD=7.59) in single-words and 92.00 (SD=10.14) in phrases. For liquids, the mean was 63.33 (SD=33.21) in single-words and 63.33 (SD=28.13) in phrases. For glides/glottal, the mean was 92.07 (SD=8.78) in single-words and 96.67 (SD=12.91) in phrases. For consonant clusters, the mean was 60.6 (SD=29.85) in single-words and 57.73 (SD=44.53) in phrases.

In the 3-year-old TD children, a large effect size was found for stops, a medium effect size for fricatives and affricates, and a small effect size for nasals and glides/glottal. There was a negligible effect size for liquids, and consonant clusters.

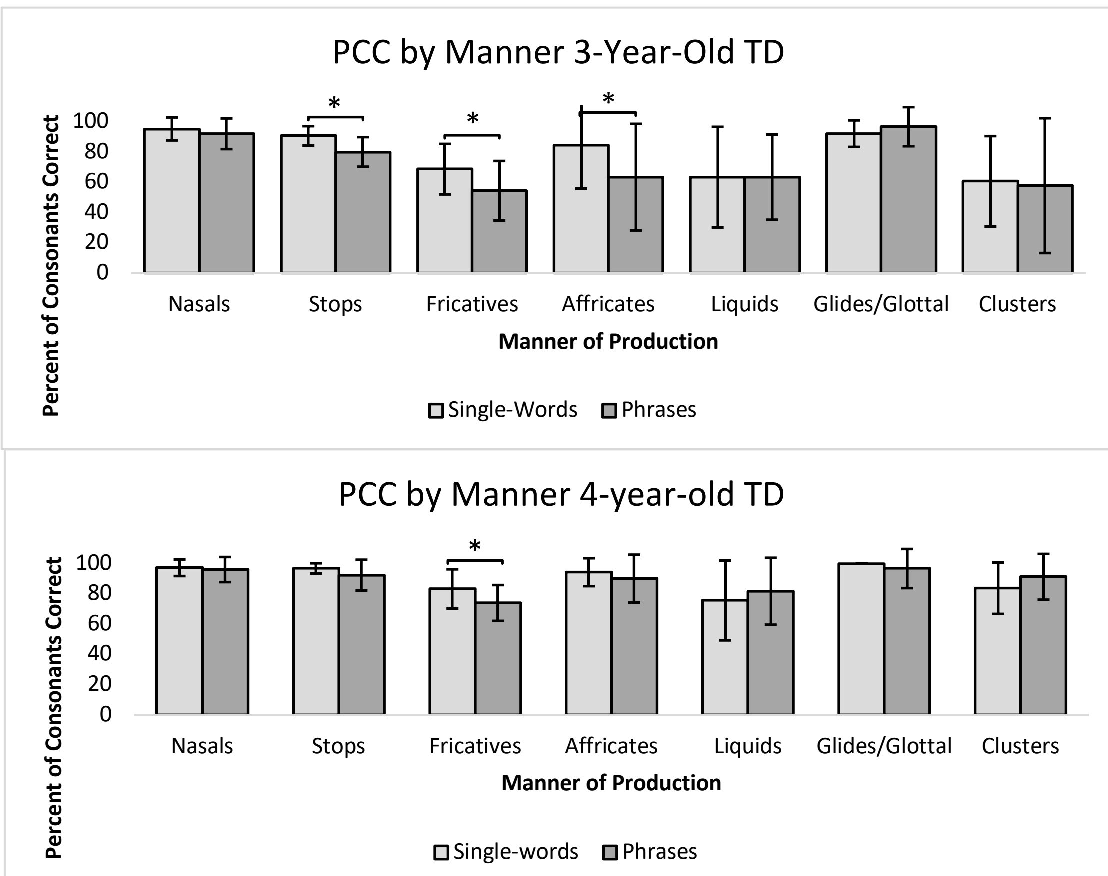
When examining PCC by Manner the 4-year-old TD children, only fricatives were observed to be statistically significant (F (1,14) = 18.94, $p = <.001$, $\eta^2 = .12$). The mean speech accuracy for fricatives was 83.20 (SD=12.97) in single-words, and was lower in phrases with a mean of 73.93 (SD=11.84).

No statistically significant difference was observed for nasals (F (1,14) = 0.57, $p = .46$, $\eta^2 = .007$), stops (F (1,14) = 3.56, $p = .08$, $\eta^2 = .05$), affricates (F (1,14) = 1.41, $p = .25$, $\eta^2 = .02$), liquids (F (1,14) = .0.68, $p = .42$, $\eta^2 = .01$), glides/glottal (F (1,14) = 1, $p = .33$, $\eta^2 = .03$), or consonant clusters (F (1,14) = 1.33, $p = .26$, $\eta^2 = .05$). For nasals, the mean was 97.20 (SD=5.49) in single-words and 96.00 (SD=8.28) in phrases. For stops, the mean was 96.80 (SD=3.36) in single-words and 92.33 (10.15) in phrases. For affricates, the mean was 94.27 (SD=9.22) and 90.00 (SD=15.81) in phrases. For liquids, the mean was 75.60 (SD=26.35) in single-words and 81.67 (SD=22.09) in phrases. For glides/glottal, the mean was 100 (SD=0) in single-words and 96.67 (SD=12.91) in phrases. Finally, for consonant clusters, the mean was 83.67 (SD=16.98) in single-words and 91.20 (SD=15.11) in phrases.

In the 4-year-old TD children, a medium effect size was found for fricatives, a small effect size for stops, affricates, liquids, glides/glottal, and consonant clusters. Nasals had a negligible effect size.

**Figure 10**

*PCC by Manner between the GFTA-3 and AEPS for the TD children*




Note. * denotes p = <0.05

***Percent of Consonants Correct by Manner in the speech delay groups***

PCC by manner for the children with speech delays was examined using descriptive statistics. Figure 11 presents PCC by Manner in the children with speech delays between the GFTA-3 and AEPS. The 3-year-old children with speech delays had the highest accuracy with glides/glottal, followed by nasals and stops in the single-word articulation task. Speech accuracy in the phrase repetition task was the highest for glides/glottal, followed by stops. The mean for glides/glottal was 72.22 (SD=9.62) in single-words, increasing to 83.33 (SD=28.87) in phrases. The mean for nasals was 70.59 (SD=36.74) in single-words, decreasing to 46.67 (SD=23.09) in phrases. The mean for stops was 70.27 (SD=7.15) in single-words, which decreased to 66.67(SD=21.73) in phrases.

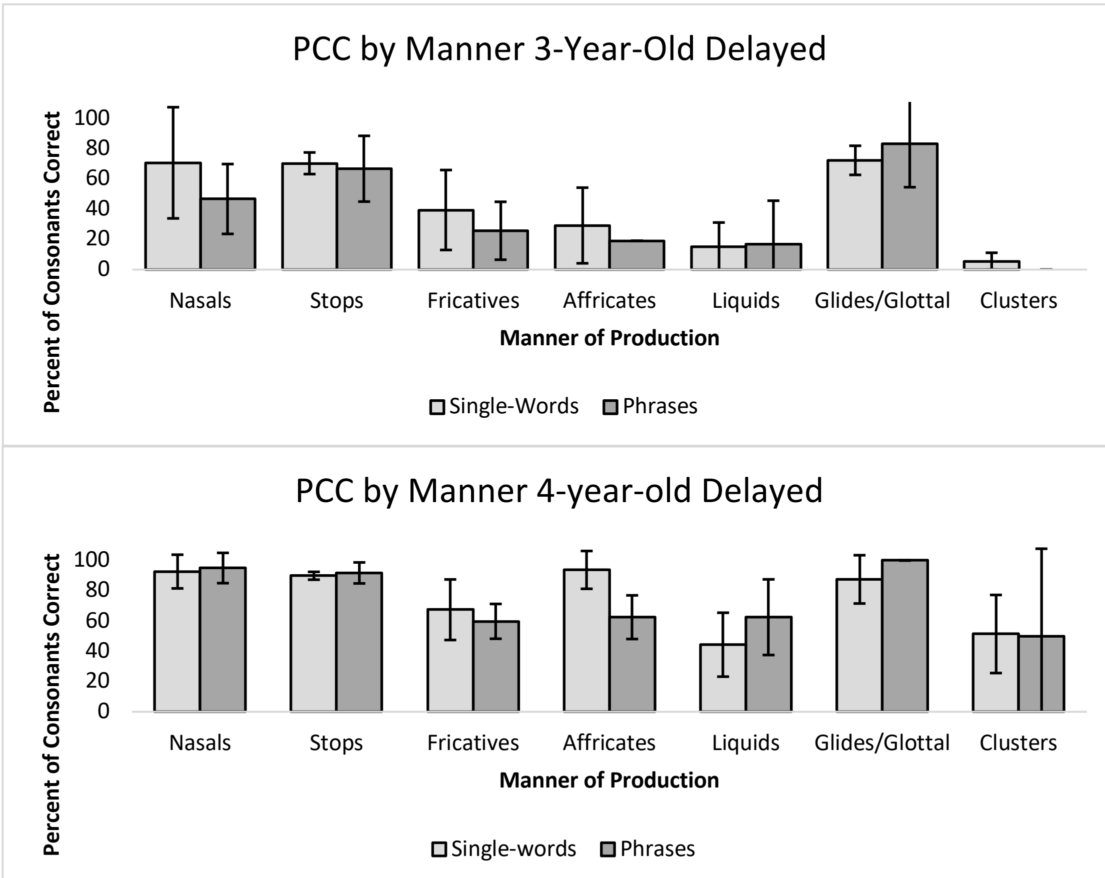
Accuracy for the 3-year-old children with speech delays was considerably low for consonant clusters, followed by liquids, affricates, and then fricatives in the single-word articulation task. The mean for consonant clusters was 5.56 (SD=5.56) in single-words, while the mean for the phrases was 0 (SD=0). The mean for liquids was 15.15 (SD=15.96) in single-words, slightly increasing to 16.67 (SD=28.87) in phrases. The mean for affricates was 29.17 (SD=19.09) in single-words, decreasing to 25.00 (SD=0) in phrases. The mean for fricatives was 39.39 (SD=26.42) in single-words, which decreased to 25.67 (SD=19.14) in phrases.

For PCC by Manner for the 4-year-old children with speech delays, the highest speech accuracy was observed for affricates, followed closely by nasals in the single-word articulation task. In the phrase repetition task, was glides/glottal, followed by nasals and stops. For affricates, the mean was 93.75 (SD=12.50) in single-words, decreasing to 62.50 (SD=14.43) in phrase. For nasals, the mean was 92.65 (SD=11.14) in single-words, increasing to 95.00 (SD=10.00) in phrases. For stops, the mean was 89.87 (SD=2.59) in single-words and was higher in phrases with a mean of 91.75 (SD=6.94). For glides/glottal, the mean was 87.50 (SD=15.96) in single-words, increasing to 100 (SD=0) in phrases.

The 4-year-old children demonstrated the lowest speech accuracy for liquids, followed by consonant clusters, and fricatives in the single-word articulation task. For liquids, the mean was 44.32 (SD=21.12) in single-words, increasing to 62.50 (SD=25.00) in phrases. For consonant clusters, the mean was 51.39 (SD=25.81) in single-words, slightly decreasing to 50.00 (57.74) in phrases. Please note that the standard deviation reflects a higher PCC for some of the 4-year-old children. For fricatives, the mean was 67.43 (SD=20.01) in single-words, which decreased to 59.75 (SD=11.50) in phrases.

**Figure 11**

*PCC by Manner between the GFTA-3 and AEPS for the children with speech delays*




Note. * denotes p = <0.05

***Percent of Consonants Correct by Manner Between Ages in the GFTA-3***

To examine PCC by manner for the 3- and 4-year-old TD children in the GFTA-3, an ANOVA was performed. Figure 12 presents PCC by Manner in the single-word articulation task for the TD children and children with speech delays. When examining PCC by Manner in the TD groups for the single-word articulation task, statistically significant increases were observed for stops ($F$ (1, 28) = 11, $p$ = .003, $\eta^2$ = .22), fricatives (F (1, 28) = 7.17, *p* = .012, $\eta^2$ = .20), glides/glottals (F (1, 28) = 12.25, *p* = .002, $\eta^2$ = .30), and consonant clusters (F (1, 28) = 6.77, *p* = .015, $\eta^2$ = .19) between the 3- and 4-year old children. Notably, medium effect sizes were observed across these manner classes when comparing the two age groups.

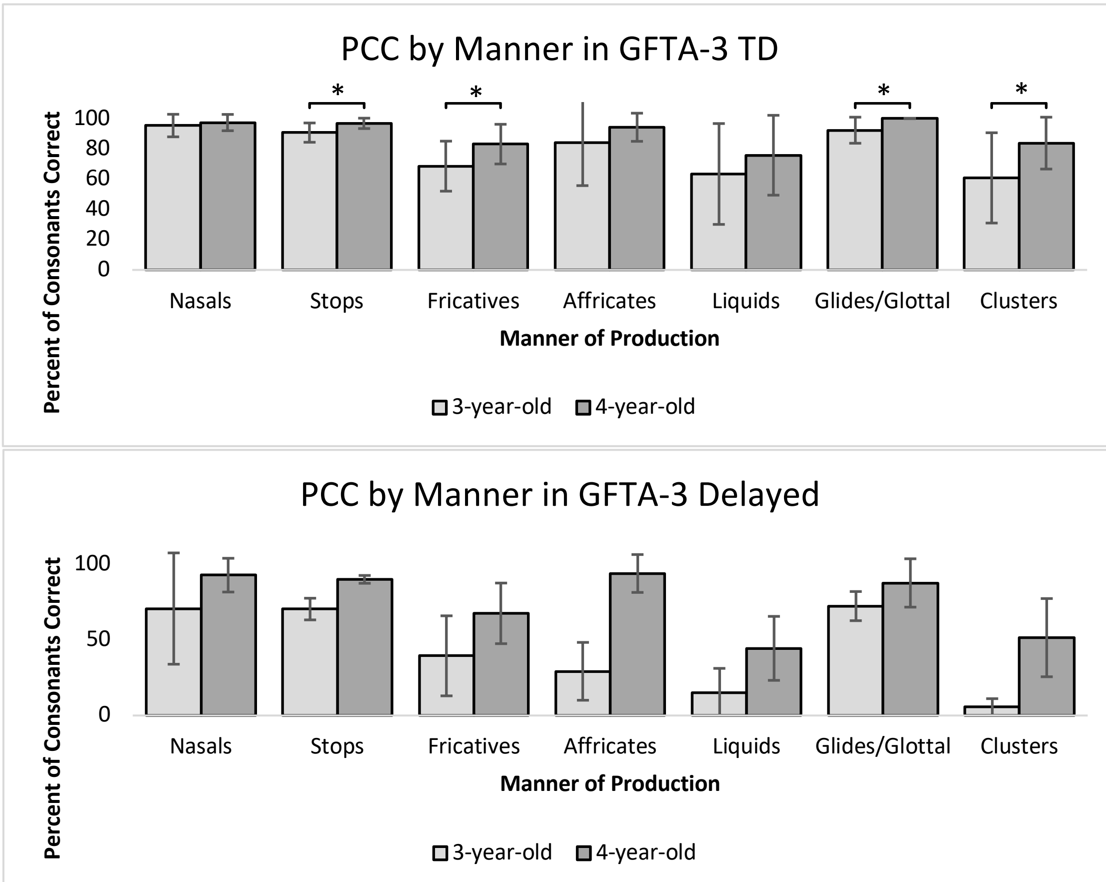
For stops, the mean for the 3-year-old TD children was 90.63 (SD=6.37) and 96.74 (SD=3.43) for the 4-year-old TD children. For fricatives, the mean for the 3-year-old TD children was 68.49 (SD=16.51), increasing to 83.03 (SD=13.10) for the 4-year-old TD children. For glides/glottal, the mean for the 3-year-old TD children was 92.22 (SD=8.61) and 100 (SD=0) for the 4-year-old children. For consonant clusters, the mean increased from 60.74 (SD=8.61) for the 3-year-old TD children to 83.70 (SD=17.12) for the 4-year-old TD children.

No statistically significant difference was observed for nasals (F (1, 28) = 0.68, *p* = .42, $n^2$ = .20), affricates (F (1, 28) = .1.65, *p* = .21, $\eta^2$ = .05), or liquids (F (1, 28) = 1.26, p = .27, $\eta^2$ = .045) at the single-word level between the 3- and 4-year-old children. For nasals, the mean for the 3-year-old TD children was 95.29 (SD=7.44) and 97.26 (SD=5.38) for the 4-year-old TD children. For affricates, the mean for the 3-year-old TD children was 84.17 (SD=28.53), while the 4-year-old TD children had a mean of 94.17 (SD=9.29). For liquids, the mean for the 3-year-old TD children was 63.33 (SD=33.29), whereas the 4-year-old TD children had a mean of 75.70 (SD=26.36). A medium effect size was observed for nasals, while small effect sizes were found for affricates and liquids.

The PCC by manner for the children with speech delays in the GFTA-3 was examined using descriptive statistics. The 3-year-old children with speech delays had the highest speech accuracy for glides/glottal, nasals, and stops, while the 4-year-old children had the highest speech accuracy for affricates and nasals. Similar to the TD children, increases in PCC were observed for all manner of productions in the 4-year-old children with speech delays. The mean for the nasals was 70.59 (SD=36.74) for the 3-year-old children, increasing to 92.65 (SD=11.14) for the 4-year-old children with speech delays. For the 3-year-old children, the mean for the stops was 70.27 (SD=7.15), and increased to 89.87 (SD=2.59) for the 4-year-old children. The mean for the fricatives for the 3-year-old children was 39.39 (SD=26.42), increasing to 67.43 (SD=20.01) for the 4-year-old children. The mean for the affricates was 29.17 (SD=19.09) in the 3-year-old children, increasing considerably to 93.75 (SD=93.75) in the 4-year-old children. The mean for the liquids was 15.15 (SD=15.96) in the 3-year-old children, increasing to 44.32 (SD=21.12) in the 4-year-old children. The mean for the glides/glottal was 72.22 (SD=9.62) in the 3-year-old children with an increase to 87.50 (SD=15.96) in the 4-year-old children. Finally, the mean for the consonant clusters was 5.56 (SD=5.56), which increased to 51.39 (SD=25.81) in the 4-year-old children with speech delays.

**Figure 12**

*PCC by Manner in the GFTA-3 between ages*




Note: * denotes p = <0.05

### *Percent of Consonants Correct by Manner Between Ages in the AEPS*

PCC by manner in the AEPS between the 3- and 4-year-old TD children and children with speech delays was examined using an ANOVA. Figure 13 presents PCC by Manner in the phrase repetition task for the TD children and children with speech delays. A statistically significant increase was found for stops ($F(1, 28) = 11.48$, $p=.002$, $\eta^2 = .29$), fricatives ($F(1, 28) = 10.94$, $p=.003$, $\eta^2 = .28$), affricates ($F(1, 28) = 7.17$, $p=.012$,

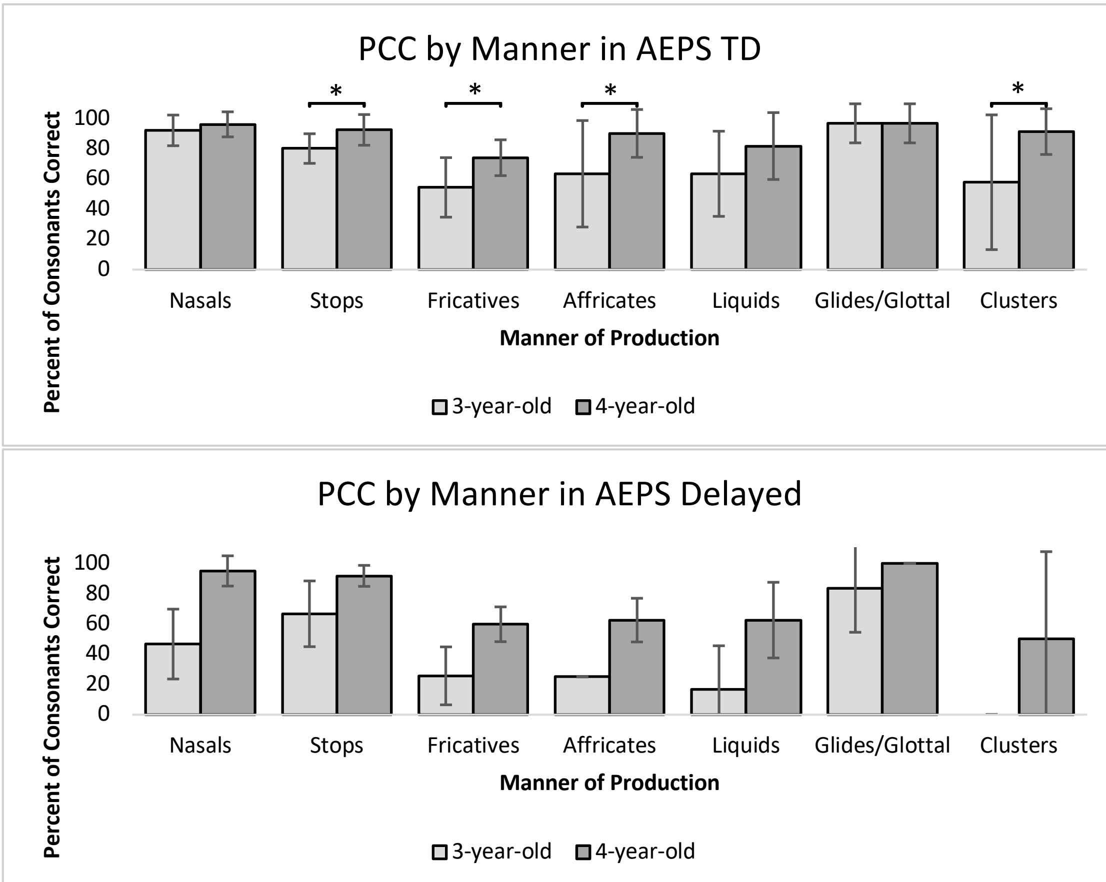
$\eta^2 = .20$), and consonant clusters ($F(1, 28) = 7.6$, $p$=.01, $\eta^2 = .21$) between the 3- and 4-year old children. For stops, the mean increased from 80.00 (SD=9.78) for the 3-year-old TD children to 92.33 (SD=10.15) for the 4-year-old TD children. For fricatives, the mean for the 3-year-old TD children was 54.33 (SD=19.67), increasing to 73.93 (SD=11.84) for the 4-year-old TD children. For affricates, the mean for the 3-year-old TD children was 63.33 (SD= 35.19), increasing to 90.00 (SD=15.81) for the 4-year-old TD children. For consonant clusters, the mean of 57.73 (SD=44.53) increased for the 3-year-old TD children to 91.20 (SD=15.11) for the 4-year-old TD children. Large effect sizes were evident for stops, fricatives, affricates, and consonant clusters.

No statistically significant difference was observed for nasals ($F(1, 28) = 1.4$, $p = .25$, $\eta^2 = .04$), liquids ($F(1, 28) = 3.94$, $p = .05$, $\eta^2 = .12$), glides/glottal ($F(1, 28) = 0$, $p = 1$, $\eta^2 = 0$) at the phrase level. For nasals, the mean for the 3-year-old TD children was 92.00 (SD=10.14) and 96.00 (SD=8.28) for the 4-year-old TD children. For liquids, the mean for the 3-year-old TD children was 63.33 (SD=28.14), while the mean was 81.67 (SD=22.09) for 4-year-old TD children. For glides/glottals, the mean was the same for the 3- and 4-year-old TD children of 96.67 (SD=12.91). A small effect size was noted for nasals, while a medium effect size was observed for liquids. There was an insignificant effect size for glides/glottal.

Descriptive statistics was used to examine the PCC by manner for the children with speech delays in the AEPS. The 3-year-old children with speech delays had the highest speech accuracy for glides/glottal and stops, while the 4-year-old children had the highest speech accuracy for glides/glottal, nasals, and stops. Similar to the TD children and as observed in the GFTA-3, variable increases were observed for all manner of productions in the 4-year-old children with speech delays compared to the 3-year-old children with speech delays. The mean for the nasals was 46.67 (SD=23.09) for the 3-year-old children, increasing to 95.00 (SD=10.00) for the 4-year-old children with speech delays. For the 3-year-old children, the mean for the stops was 66.67 (SD=21.73), and increased to 91.75 (SD=6.94) for the 4-year-old children. The mean for the fricatives for the 3-year-old children was 25.67 (SD=19.14), increasing to 59.75 (SD=11.50) for the 4-year-old children. The mean for the affricates was 25.00 (SD=0.00) in the 3-year-old children, increasing considerably to 62.50 (SD=14.43) in the 4-year-old children. The mean for the liquids was 16.67 (SD=28.87) in the 3-year-old children, increasing to 62.50 (SD=25.00) in the 4-year-old children. The mean for the glides/glottal was 83.33 (SD=28.87) in the 3-year-old children with an increase to 100.00 (SD=0.00) in the 4-year-old children. In the 3-year-old children with speech delays, no consonant clusters were produced accurately. The mean for consonant clusters increased to 50.00 (SD=57.74) in the 4-year-old children with speech delays.

**Figure 13**

*PCC by Manner in the AEPS between ages*




Note: * denotes p = <0.05

**Major Findings for Q2**

- The 3-year-old TD children demonstrated a significant decrease in PCC for stops, fricatives, and affricates at the phrase level.
- For the 3-year-old TD children, only glides/glottal showed a slightly higher mean PCC at the phrase level, though it was not statistically significant.

- In the 4-year-old TD children, only fricatives showed a significantly lower PCC between the GFTA-3 and the AEPS.
- For the other manner of productions in the 4-year-old TD children, liquids and consonant clusters showed a higher PCC in the AEPS, while all other manner of productions showed a decrease. None of these changes were noted to be statistically significant.
- The 3-year-old children with speech delays showed lower PCCs for nasals, stops, fricatives, affricates, and consonant clusters, and higher PCC for liquids and glides/glottal at the phrase level.
- The 4-year-old children with speech delays showed lower PCC for fricatives, affricates, and consonant clusters, and higher PCC for nasals, stops, liquids, and glides/glottal at the phrase level.
- Age was a determining factor for increased total PCC and PCC by Manner in the 4-year-old children.
- Improved total PCC was noted at the phrase level, though this should be viewed with caution due to the disproportionate number of opportunities between the GFTA-3 (141) and the AEPS (39).

## Research Question 3: Developmental/Phonological Processes

What are the types and frequency of phonological processes being produced among the TD children and children with speech delays for 3-3;11 and 4-4;11-year-olds?

### *Top Ten Developmental/Phonological Processes in the GFTA-3*

To address research question 3, the types and frequency of each developmental/phonological process was examined. The Khan-Lewis Phonological

Analysis-Third Edition (KLPA-3) was used to examine the types of developmental/phonological processes produced by the TD children and the children with speech delays. Figure 14 presents the top ten processes for each age group for the TD children and children with speech delays. Appendix D lists all the developmental/phonological processes that were examined. Both TD children and children with speech delays used manner, reduction, and 1-3 supplemental processes. In addition, the TD children used voicing processes and the children with speech delays used place processes. The 3- and 4-year-old TD children produced the same type of processes, except initial devoicing observed in the 3-year-old TD group and alveolarization observed in the 4-year-old TD group. There was a reduction in the frequency of occurrence of the same processes in the 4-year-old TD group. The 3-year-old children with speech delays demonstrated atypical processes such as backing to velars or /h/, velar fronting, palatal fronting, and syllable reduction. The 4-year-old children with speech delays demonstrated velar fronting as well.

**Figure 14**

*Top ten developmental/phonological processes produced in the GFTA-3*

| | 3-year-old TD (n=15) Mean (S.D.) | 4-year-old TD (n=15) Mean (S.D.) | 3-year-old Delayed (n=3) Mean (S.D.) | 4-year-old Delayed (n=4) Mean (S.D.) |
|---|---|---|---|---|
| Manner | Gliding 6.33 (6.29) | Gliding 3.00 (3.82) | Gliding 5.00 (1.73) | Gliding 8.25 (5.91) |
| | Stopping 2.93 (1.98) | Stopping 1.93 (1.58) | Stopping 7.67 (0.58) | Stopping 2.75 (0.96) |
| | Stridency deletion 1.40 (1.88) | Stridency deletion 0.80 (0.94) | Stridency deletion 13.67 (5.77) | Stridency deletion 1.25 (1.50) |
| | Vocalization 5.27 (5.44) | Vocalization 4.20 (4.66) | Vocalization 10.33 (4.04) | Vocalization 9.50 (3.51) |
| Place | | | Palatal fronting 4.00 (2.00) | |
| | | | Velar fronting 3.33 (3.21) | Velar fronting 1.25 (1.26) |
| | | | Backing to velars or /h/ 8.67 (7.77) | |
| Reduction | Cluster simplification 3.07 (3.83) | Cluster simplification 0.93 (1.58) | Cluster simplification 18.00 (1.73) | Cluster simplification 2.00 (3.37) |
| | Deletion of final consonant 0.87 (1.25) | Deletion of final consonant 0.67 (0.98) | Deletion of final consonant 7.67 (8.62) | Deletion of final consonant 1.75 (2.36) |
| | | | Syllable reduction 4.00 (2.00) | |
| Voicing | Final devoicing 1.00 (1.13) | Final devoicing 0.33 (0.62) | | |
| | Initial devoicing 1.27 (1.67) | | | |
| Other | Labialization 2.60 (2.56) | Labialization 0.80 (1.08) | Labialization 3.33 (3.21) | Labialization 1.25 (0.96) |
| | Dentalization 4.07 (5.24) | Dentalization 2.20 (4.49) | | Dentalization 5.75 (7.14) |
| | | Alveolarization 0.27 (0.46) | | Alveolarization 1.50 (1.29) |

Note. Values are presented as the mean number of occurrences with the standard deviation in parentheses

# CHAPTER 5

# DISCUSSION

This study investigated the types of traditional speech errors (SODA) and speech sound accuracy (PCC and PCC by Manner) exhibited by preschool-age children across two linguistic contexts–words and phrases. Additionally, the study explored the phonological processes present in their single-word articulation. The discussion will begin by addressing traditional speech errors (SODA) and will move into discussion of percent of consonants correct (PCC). Next, developmental/phonological processes will be discussed, followed by a detailed comparison of performance between the GFTA-3 and American English Phrase Sample (AEPS). Clinical implications of the findings of the current study will be addressed. Finally, the discussion will end with limitations of the study, overall conclusions, and ideas for future research.

## Traditional Speech Errors (SODA)

### *Type of Speech Errors*

Statistically significant differences and large effect sizes for the number of total SODA errors were observed in both the GFTA-3 and the AEPS between the 3- and 4-year-old TD children. A similar pattern of fewer total errors for the 4-year-olds than the 3-year-olds was observed in the children with speech delays. These findings align with what is widely understood about overall speech development across multiple languages, in which speech acquisition and mastery have an inverse relationship with total number of errors (McLeod & Crowe, 2018). Overall, the results of the AEPS show a similar pattern of fewer total errors in the older group as observed in the GFTA-3.

The results of the current study support previous studies that have shown TD children produce substitution errors most often, followed by either an equal proportion of omission and distortion errors or slightly higher omission errors than distortion errors (Brosseau-Lapre & Roepke, 2019; Neam et al., 2020). Brosseau-Lapre & Roepke (2019) examined the speech errors of children 4 and 5 years of age with TD and speech sound disorder (SSD) in mono-, di-, and multisyllabic words. They found that substitution errors were the most common type of error in TD children, followed by a generally equal proportion of omission and distortion in mono- and di-syllabic words, and omission errors in multisyllabic words (Brosseau-Lapre & Roepke, 2019). A more recent study by Neam et al., (2020) looked at the types of speech errors in 4- and 5-year-old children with and without a history of late talking in a single-word polysyllable assessment and also found substitution errors were the most common, followed by omissions, distortions, and additions, respectively.

In children with repaired cleft palate up to the age of 5, distortion errors were reported to be the most prevalent, while substitution errors were the second most common (Shiraganvi et al., 2011). However, a more recent study by Lien et al. (2023) showed that phonological errors, mostly substitutions, were most common in children with cleft palate 4 to 7 years of age. Substitution errors, which are produced by all children during typical speech sound development, are believed to reflect the usage of early-acquired sounds that are easier to produce in place of those acquired later (Riper & Erickson, 1996). While the current study similarly reflects a high number of substitution errors across both the GFTA-3 and AEPS, it does not reflect the high number of distortion errors observed by Shiraganvi et al. (2011) in the cleft palate population. The findings from Shiraganvi et al. (2011) indicate that distortion errors may be more likely to occur in children whose speech sound disorder is structural in nature, such as a history of a cleft palate. Of note, the 3-year-old children with speech delays showed a high number of omission errors across all groups. This finding suggests that omissions are a reflection of early errors and substitutions are more prominent as speech development progresses. Findings from the current study corroborate findings from previous studies on children with speech delays or speech sound disorders, showing that omission errors are more likely to be indicative of a speech sound deficit that is likely functional in nature (Liu & Chien, 2020; Shriberg et al., 2005; Macrae & Tyler, 2014).

***Errors by Age Group and Word Position***

The age-related decrease in the total number of errors across all word positions between the 3- and 4-year-old children in both the GFTA-3 and AEPS corroborates findings from previous research (Kenney & Prather, 1986; Prather et al., 1975).

Previous studies have shown that accuracy of speech productions in initial word position is generally better than in final word position in TD children and children with SSD (Davis, 1998; Kenny & Prather, 1986). Davis (1998) examined the speech accuracy in different word positions of ten children aged 3;8 to 5;10 with phonological disorders and found that PCC was greater in initial word position with a PCC of about 73% than in final word position with a PCC of about 60%. Another study found similar results when investigating the speech of 360 children aged 2;5 to 5;5, in which more errors were produced in the final position than the initial position (Kenny & Prather, 1986). Results in the current study of both the TD and speech delay groups showed that on the GFTA-3, the 3-year-olds had more errors in the initial position; however, the findings from the 4-

year-olds showed the opposite findings, similar to the literature. The results in the AEPS showed that the children in the TD and speech delay groups had about equal errors in initial and final word position, with fewer errors in the 4-year-olds than the 3-year-olds. The differences between the single words and phrases may likely be due to the AEPS being constructed to balance initial and final word targets in the same phrase and having fewer target words than the GFTA-3. The higher number of errors in initial word position in the 3-year-old GFTA-3's may indicate a developmental trend that was not captured in the literature.

## Percent of Consonants Correct (PCC)

### *Total PCC*

The TD and speech delays children in this study showed a significant difference between total PCC at 3 and 4 years of age on both single words and phrases. These findings align with international research and other studies of English-speaking children (McLeod & Crowe, 2018; Dodd et al., 2003; Campbell et al., 2007; Watson & Scukanec, 1997; Clausen & Fox-Boyer, 2017). McLeod & Crowe (2018) examined multiple international studies that examined PCC in single-word samples which demonstrated an age-related increase in PCC. The other studies reported similar results where PCC increased between 3 and 4 years of age (Dodd et al., 2003; Campbell et al, 2007; Watson & Scukanec, 1997; Clausen & Fox-Boyer, 2017).

Further, the findings from this study support previous research on the speech accuracy of different speech materials, which revealed higher PCC for word naming compared to sentence repetition task in 5-year-old children, in which a median PCC of about 86% was achieved for a word naming task compared to a median of about 81% for a sentence repetition task (Klintö et al., 2011). The children with speech delays showed greater differences between single words and phrases than the TD children.

A study by Liu & Chien (2020) examined the PCC of 4-year-old TD children and children with speech sound disorder (SSD), in which the children with SSD had a mean PCC of 72%, while the TD group had a mean PCC of 95%. In the current study, of the 4-year-old TD children and children with speech delays, lower PCC was noted in the latter, supporting findings from Liu & Chien's (2020) study.

Shriberg & Kwiatkowski (1982) described four speech sound severity levels based on PCC for children with developmentally delayed speech: mild (>85% PCC), mild-moderate (65-85% PCC), moderate-severe (50-65% PCC), and severe (<50% PCC). The severity levels were created to provide a means of diagnostic classification for phonological disorders; however, this data was based on information from older children with a mean age of 5.75 years (Shriberg & Kwiatkowski, 1982). The 3-year-old children with speech delays in this study placed in the severe range, while the 4-year-old children with speech delays placed in the mild-moderate range. Moreover, the children with speech delays also demonstrated a similar age-related effect on PCC, where the older 4-year-olds demonstrated higher PCC than the 3-year-olds. Results from both the TD children and children with speech delays support the typical pattern of development, in which children's phonemic inventories expand over time and, in turn, PCC increases.

***PCC by Manner***

Due to structural abnormalities and compensatory mislearning, children with CP+/-L are known to have lower accuracy for manner classes that require high pressure (e.g., stops, fricatives, affricates) (Nagarajan et al., 2009). The speech accuracy for different manner classes was examined to understand the relationship between the two age groups and the two linguistic contexts (word versus phrase level). Existing literature on age-related effects of PCC by manner or between linguistic contexts was not available for this age range; therefore, the following discussion will provide an overall assessment of children's performance of each manner class. When examining PCC by manner in 8 monolingual TD children aged 3;0-4;0 on a single-word articulation assessment, Fabiano-Smith & Goldstein's (2010) study found a mean of about 92% for nasals, 88% for stops, 87% for glides, 84% for fricatives, 75% for affricates, and 70% for liquids. Wren et al. (2020) also examined the PCC of manner classes in connected speech of 776 5-year-olds in which they found the PCC to be the highest for nasals, followed by glides, stops, fricatives, liquids, clusters, and affricates, respectively. Results from this study vary slightly from previous studies; however, it should be noted that a similarity of the top three manner classes was observed. The top three highest PCCs across previous studies and the current study on both the GFTA-3 and AEPS were nasals, glides, and stops, which aligns with normative data on individual speech sound acquisition (Crowe & McLeod, 2020). Interestingly, in the current study, affricates had the next highest PCC across all ages and linguistic contexts, whereas the previous studies found affricates to be the least accurate manner class.

**Developmental/Phonological Processes**

Some phonological processes are expected in ages this young, as children are still developing their speech sound abilities; however, these should steadily disappear with age. Several studies have been completed on the common types of phonological processes observed in children and the age of elimination; however, Cohen & Anderson

(2011) brought forth a concern about the difficulty relating existing data to clinical decision-making due to the small sample sizes and different interpretations of findings. The studies that are being used to discuss the current study's results were not clear about the timeline for the age of elimination (Khan & Lewis, 2015; Grunwell, 1997; Bowen, 1998; Shipley & McAfee, 2021). In other words, it's not clear if the "By age 3" or "By age 4" refers to 3;0 or 3;11, or 4;0 or 4;11. Thus, the current study uses data from several sources to discuss the phonological processes observed by each group.

Of the top ten processes in the 3-year-old TD group, voicing errors, such as final devoicing and initial devoicing, are expected to be eliminated by age 3 according to normative data from several sources (Khan & Lewis, 2015; Grunwell, 1997; Bowen, 1998; Shipley & McAfee, 2021). The processes expected to be eliminated by age 4 are final consonant deletion, cluster simplification, and stopping of most fricatives and affricates except /θ, ð/ (Khan & Lewis, 2015; Grunwell, 1997; Bowen, 1998; Shipley & McAfee, 2021). All of these processes were observed in both age groups as one of the top ten, suggesting that the age of elimination of these processes is later than indicated in the literature.

The 3-year-old children with speech delays produced an atypical error commonly seen in children with phonological disorders and/or with cleft palate: backing to velars or /h/ (Ceron et al, 2017; Waring & Knight, 2013; Nagarajan et al., 2009; Dodd, 2003). Of note, the speech sample of the child identified with a speech delay who had a history of speech therapy contained many instances of /h/ as a replacement for multiple consonants, which may have skewed the results for this group.

## Single Words vs Phrases

The results from the AEPS have similarities to those obtained from the GFTA-3, which highlights the clinical value of the AEPS. One major similarity between the AEPS and GFTA-3 was highlighted in the SODA analysis. Across both assessments, substitutions emerged as the most common error type, while additions were the least common among the TD and speech delay groups. This demonstrates that the AEPS can similarly be used to evaluate traditional speech errors.

Additionally, when examining the progression of the number of errors produced across the two age groups, the children demonstrated a comparable decrease in the number of errors in the AEPS as observed in the GFTA-3. This age-related pattern suggests that the development of speech sound abilities remains consistent regardless of the linguistic context, further supporting the clinical use of the AEPS.

PCC was examined between the GFTA-3 and AEPS to examine whether speech accuracy varies between linguistic contexts. The findings from this study support previous studies on the speech accuracy of different speech materials, which revealed higher PCC for word naming compared to sentence repetition task, in which a median PCC of about 86% was achieved for a word naming task compared to a median of about 81% for a sentence repetition task (Klintö et al., 2011). However, it is important to note the differences observed when PCC by manner was examined. Lower accuracy in the production of stops, fricatives, and affricates was observed in the 3-year-olds, while lower accuracy for fricatives was observed in the 4-year-olds. These differences were found to be statistically significant between the GFTA-3 and the AEPS, suggesting potential difficulties in speech sound accuracy associated with increased linguistic demands. However, it can also be proposed that developmental mastery of certain manner classes may not be affected by increased linguistic complexity in the phrases, as the other manner classes show small or negligible effect sizes.

In summary, the strong similarities in results between the GFTA-3 and AEPS show that the AEPS is a valuable tool for evaluating speech sound abilities. It also suggests the potential use of the AEPS beyond just the cleft population.

**Clinical Implications**

The American English Phrase Sample is a useful tool for collecting a speech sample of children under the age of five in the craniofacial population, who find it difficult to imitate the stimuli in the longer American English Sentence Sample. The phrases, modeled with the same criteria as the sentences, isolate specific phonemes to assess cleft palate speech characteristics, such as hypernasality, audible nasal air emission, and hyponasality, in addition to developmental speech sound errors and cleft-related errors (e.g., glottal stop substitutions, nasal emission). Results of this study provide normative guidelines for the American English Phrase Sample, which will be useful in contextualizing the speech production and speech accuracy of children in the craniofacial population.

The use of a phrase repetition task offers significant clinical value, as it yields comprehensive data mirroring spontaneous speech, which would be useful in settings where connected speech samples are not collected as a routine measure due to time constraints or client characteristics. Additionally, the phrases provide controlled stimuli for assessing individual speech sounds, which may be beneficial even outside of the craniofacial population for highly unintelligible children.

Finally, this study contributes normative data for PCC and PCC by manner of production in the GFTA-3 and AEPS, adding further understanding of speech characteristics and development of preschool-aged children. PCC is widely used for clinical assessment of speech severity and speech outcomes. The normative data enhances the clinical utility of the study's findings by providing clinicians with comprehensive data points for assessing speech sound accuracy and identifying potential areas of concern or deviation from typical development.

**Limitations**

While the current study provides valuable normative data on speech errors and speech accuracy for the American English Phrase Sample, there are some limitations. The larger study originally intended to recruit a more balanced number of males and females of TD children; however, there was a greater number of males (n=18) compared to females (n=12) in the current study for the TD children. While the age groups were balanced evenly, there may be a gender bias in the resulting data. Future studies using the American English Phrase Sample should control for gender.

Another limitation was the number of children with a speech delay. Given that recruitment was targeted toward TD children, there was a very small number of children with speech delays that were described in this study, which prevented statistical analysis from being conducted for this sample. Future studies would benefit from obtaining more data from children with speech delays with and without language delays.

Finally, phonetic transcriptions of the two speech samples were performed on video-recorded speech samples. The inclusion of the video recordings of speech assisted in identifying placement and manner of productions during transcriptions. The procedures used aimed to provide a high-quality video and audio recording; however, some recordings were obtained outside of the lab setting in less-controlled environments, resulting in some background noise, which may have affected the quality of the recordings.

**Conclusions and Future Directions**

The results of this study provide normative data for the American English Phrase Sample, which will serve as a reference in future studies to compare to children with CP+/-L. This study also provides additional data on the types of traditional speech errors that preschool-age children are producing, and the effect of word position in the AEPS in comparison to single-word articulation. Additionally, it shows how PCC and PCC by Manner changes in the AEPS. Finally, this study provides additional normative data on the types and frequencies of phonological processes present in preschool-age children in a single-word articulation task. The conclusions of this study support the claim that children's performance on the AEPS closely mirrors that of the GFTA-3, with only slight variations depending on contextual factors.

As expected in typical speech development, the 4-year-old TD children performed the highest on all measures. They produced the fewest total errors, the least amount of each error type, and had the highest PCC and PCC for each manner class. When comparing performance on the AEPS to the GFTA-3, the results were different based on age. The 3-year-old typically developing children demonstrated a significantly lower total PCC in the AEPS, whereas the 4-year-old typically developing children did not. When examining PCC by Manner, the 3-year-olds again demonstrated a difference from the 4-year-olds, showing a significantly lower PCC for stops, fricatives, and affricates in the

AEPS. The 4-year-old TD children only showed a significantly lower PCC for fricatives in the AEPS. Place of articulation was not examined in this study but further exploration into this area in TD children using the GFTA-3 and AEPS would be useful in understanding normative development and speech accuracy in relation to placement for comparison with children with CP+/-L.

Age was also shown to be a factor in the number of phonological processes still present in the 4-year-old children. While the 3- and 4-year-olds produced the majority of the same processes, each of these processes decreased in frequency.

Only preliminary data could be obtained from the children with speech delays due to the small number. A critical pattern that merits further investigation was observed, in which the 4-year-old children with speech delays generally performed similarly to the 3-year-old TD children. Further exploration into the speech characteristics of children without a cleft condition with a speech delay would provide a unique comparison to children with a CP+/-L who often demonstrate speech delays due to their cleft condition.

# REFERENCES


American Speech-Language-Hearing Association. (n.d.). *Speech Sound Disorders: Articulation and Phonology*. American Speech-Language-Hearing Association. https://www.asha.org/practice-portal/clinical-topics/articulation-and-phonology/

Bernthal, J. E., Bankson, N. W., & Flipsen, P. (2022). Speech Sound Disorders in Children: Articulation & Phonological Disorders (9th ed.). Brookes Publishing.

Bowen, C. (1998). Developmental phonological disorders: A practical guide for families and teachers. ACER Press.

Brosseau-Lapré, F., & Roepke, E. (2019). Speech errors and phonological awareness in children ages 4 and 5 years with and without speech sound disorder. *Journal of Speech, Language, and Hearing Research*, *62*(9), 3276–3289. https://doi.org/10.1044/2019_jslhr-s-17-0461

Campbell, T. F., Dollaghan, C., Janosky, J. E., & Adelson, P. D. (2007). A performance curve for assessing change in Percentage of Consonants Correct Revised (PCC-R). *Journal of speech, language, and hearing research : JSLHR*, *50*(4), 1110–1119. https://doi.org/10.1044/1092-4388(2007/077)

Campbell, Dollaghan, C. A., Rockette, H. E., Paradise, J. L., Feldman, H. M., Shriberg, L. D., Sabo, D. L., & Kurs-Lasky, M. (2003). Risk Factors for Speech Delay of Unknown Origin in 3-Year-Old Children. Child Development, 74(2), 346–357. https://doi.org/10.1111/1467-8624.7402002

Ceron, M. I., Gubiani, M. B., Oliveira, C. R., Gubiani, M. B., & Keske-Soares, M. (2017). Prevalence of phonological disorders and phonological processes in typical and atypical phonological development. Ocorrência do desvio fonológico e de processos fonológicos em aquisição fonológica típica e atípica. CoDAS, 29(3), e20150306. https://doi.org/10.1590/2317-1782/20172015306

Chacon, A., Parkin, M., Broome, K., & Purcell, A. (2017). Australian children with cleft palate achieve age-appropriate speech by 5 years of age. *International Journal of Pediatric Otorhinolaryngology*, *103*, 93–102. https://doi.org/10.1016/j.ijporl.2017.09.030

Clausen, M. C., & Fox-Boyer, A. (2017). Phonological development of Danish-speaking children: A normative cross-sectional study. *Clinical linguistics & phonetics*, *31*(6), 440–458. https://doi.org/10.1080/02699206.2017.1308014

Cohen, W., & Anderson, C. (2011). Identification of phonological processes in preschool children's single-word productions. *International Journal of Language &*

*Communication Disorders*, *46*(4), 481–488. https://doi.org/10.1111/j.1460-6984.2011.00011.x

Chapman, K. L., Baylis, A., Trost-Cardamone, J., Cordero, K. N., Dixon, A., Dobbelsteyn, C., Thurmes, A., Wilson, K., Harding-Bell, A., Sweeney, T., Stoddard, G., & Sell, D. (2016). The Americleft Speech Project: A Training and Reliability Study. *The Cleft Palate-Craniofacial Journal*, 53(1), 93–108. https://doi.org/10.1597/14-027

Crowe, K., & McLeod, S. (2020). Children's English consonant acquisition in the United States: A Review. *American Journal of Speech-Language Pathology*, *29*(4), 2155–2169. https://doi.org/10.1044/2020_ajslp-19-00168

Davis, B. L. (1998). Consistency of consonant patterns by word position. Clinical Linguistics & Phonetics, 12(4), 329–348. https://doi.org/10.3109/02699209808985228

Dodd, B., Holm, A., Hua, Z., & Crosbie, S. (2003). Phonological development: A normative study of British English-speaking children. Clinical Linguistics & Phonetics, 17(8), 617–643. https://doi.org/10.1080/0269920031000111348

Dodd, B., Reilly, S., Ttofari Eecen, K., & Morgan, A. T. (2018). Articulation or phonology? Evidence from longitudinal error data. *Clinical Linguistics & Phonetics*, *32*(11), 1027–1041. https://doi.org/10.1080/02699206.2018.1488994

Fabiano-Smith, L., & Goldstein, B. A. (2010). Phonological acquisition in bilingual Spanish-English speaking children. Journal of speech, language, and hearing research : JSLHR, 53(1), 160–178. https://doi.org/10.1044/1092-4388(2009/07-0064)

Gierut, J. A., & Morrisette, M. L. (2012). Density, frequency and the expressive phonology of children with phonological delay. *Journal of Child Language*, *39*(4), 804–834. https://doi.org/10.1017/s0305000911000304

Goldman, R., & Fristoe, M. (2015). *Goldman-Fristoe Test of Articulation-Third Edition*. (GFTA-3). Pearson.

Grunwell, P. (1997). Natural Phonology. In *The New Phonologies: Developments in Clinical Linguistics*. essay, Singular Publishing Group.

Henningsson, G., Kuehn, D. P., Sell, D., Sweeney, T., Trost-Cardamone, J. E., Whitehill, T. L., & Speech Parameters Group (2008). Universal parameters for reporting speech outcomes in individuals with cleft palate. The Cleft palate-craniofacial journal : official publication of the American Cleft Palate-Craniofacial Association, 45(1), 1–17. https://doi.org/10.1597/06-086.1

John, A., Sell, D., Sweeney, T., Harding-Bell, A., & Williams, A. (2006). The cleft audit protocol for speech—augmented: A validated and reliable measure for auditing cleft speech. *The Cleft Palate-Craniofacial Journal*, *43*(3), 272–288. https://doi.org/10.1597/04-141r.1

Kenney, K. W., & Prather, E. M. (1986). Articulation development in Preschool Children: Consistency of Productions. *Journal of Speech, Language, and Hearing Research*, *29*(1), 29–36. https://doi.org/10.1044/jshr.2901.29

Khan, L. M., & Lewis, N. P. (2015). The Khan-Lewis Phonological Assessment, Third Edition.

Klintö, K., Salameh, E. K., Svensson, H., & Lohmander, A. (2011). The impact of speech material on speech judgement in children with and without cleft palate. International journal of language & communication disorders, 46(3), 348–360. https://doi.org/10.3109/13682822.2010.507615

Lien, K. M., Scherer, N. J., Cordero, K. N., & Sitzman, T. J. (2023). Speech Production Errors in Children With Cleft Palate With or Without Cleft Lip. *Journal of Speech, Language, and Hearing Research*, *66*, 849–862. https://doi.org/https://doi.org/10.1044/2022_JSLHR-22-00264

Liu, H. M., & Chien, H. Y. (2020). Speech sound errors of Mandarin-speaking preschool children with co-occurring speech sound disorder and developmental language disorder. Clinical linguistics & phonetics, 34(12), 1130–1148. https://doi.org/10.1080/02699206.2020.1724334

Macrae, T., & Tyler, A. A. (2014). Speech abilities in preschool children with speech sound disorder with and without co-occurring language impairment. Language, speech, and hearing services in schools, 45(4), 302–313. https://doi.org/10.1044/2014_LSHSS-13-0081

McLeod, S., & Crowe, K. (2018). Children's Consonant Acquisition in 27 Languages: A Cross-Linguistic Review. *American Journal of Speech-Language Pathology*, *27*(4), 1546–1571. https://doi.org/10.1044/2018_ajslp-17-0100

McLeod, S., Harrison, L. J., & McCormack, J. (2012). Intelligibility in context scale. *Journal of Speech, Language, and Hearing Research*, *55*, 648–656. https://doi.org/10.1037/t35980-000

Morgan, A., Ttofari Eecen, K., Pezic, A., Brommeyer, K., Mei, C., Eadie, P., Reilly, S., & Dodd, B. (2017). Who to Refer for Speech Therapy at 4 Years of Age Versus

Who to "Watch and Wait"?. The Journal of pediatrics, 185, 200–204.e1. https://doi.org/10.1016/j.jpeds.2017.02.059

Nagarajan, R., Savitha, V. H., & Subramaniyan, B. (2009). Communication disorders in individuals with cleft lip and palate: An overview. Indian journal of plastic surgery : official publication of the Association of Plastic Surgeons of India, 42 Suppl(Suppl), S137–S143. https://doi.org/10.4103/0970-0358.57199

Neam, S. Y., Baker, E., Hodges, R., & Munro, N. (2020). Speech production abilities of 4- to 5-year-old children with and without a history of late talking: The tricky tyrannosaurus. International journal of speech-language pathology, 22(2), 184–195. https://doi.org/10.1080/17549507.2019.1638968

Nikhila, K. G., & Prasad, H. (2017). A Study on Patterns of Compensatory Articulation Errors with Reference to Age of Surgery in Children with Repaired Cleft Lip and Palate. *Global Journal of Otolaryngology*, *7*(2): 555706. https://doi.org/10.19080/gjo.2017.07.555706

Pitkänen, V. V., Alaluusua, S. A., Geneid, A., Vuola, P. M. B., Leikola, J., & Saarikko, A. M. (2022). How Early Can We Predict the Need for VPI Surgery?. Plastic and reconstructive surgery. Global open, 10(11), e4678. https://doi.org/10.1097/GOX.0000000000004678

Prather, E. M., & Hedrick, D. L. (1975). Articulation development in children aged two to four years. The Journal of speech and hearing disorders, 40(2), 179–191. https://doi.org/10.1044/jshd.4002.179

Preston, J., & Edwards, M. L. (2010). Phonological Awareness and Types of Sound Errors in Preschoolers With Speech Sound Disorders. *Journal of Speech, Language, and Hearing Research*, *53*(1), 44–60. https://doi.org/10.1044/1092-4388(2009/09-0021)

Preston, J. L., Hull, M., & Edwards, M. L. (2013). Preschool Speech Error Patterns Predict Articulation and Phonological Awareness Outcomes in Children With Histories of Speech Sound Disorders. *American Journal of Speech-Language Pathology*, *22*, 173–184. https://doi.org/10.1044/1058-0360(2012/12-0022)

Riper, V. C., & Erickson, R. L. (1996). *Speech Correction: An Introduction to Speech Pathology and Audiology* (9th ed.). Allyn and Bacon.

Roberts, J. E., Burchinal, M., & Footo, M. M. (1990). Phonological process decline from 2 1/2 to 8 years. Journal of Communication Disorders, 23(3), 205–217. https://doi.org/10.1016/0021-9924(90)90023-r

Shipley, K. G., & McAfee, J. G. (2021). Assessment in Speech-Language Pathology: A Resource Manual (6th ed.). Plural Publishing, Inc.

Shiraganvi, M. S., Kumar, N., Desai, A., Kiran, T., & Gopalkrishnan, K. (2011). Analysis for speech and esthetics in sixty consecutive patients with cleft lip and palate. *Journal of Oral Biology and Craniofacial Research*, *1*(1), 3–6. https://doi.org/10.1016/s2212-4268(11)60003-1

Shriberg, L. D., Austin, D., Lewis, B. A., McSweeny, J. L., & Wilson, D. L. (1997). The percentage of consonants correct (PCC) metric: extensions and reliability data. Journal of speech, language, and hearing research : JSLHR, 40(4), 708–722. https://doi.org/10.1044/jslhr.4004.708

Shriberg, L. D., & Kwiatkowski, J. (1982). Phonological disorders III: a procedure for assessing severity of involvement. The Journal of speech and hearing disorders, 47(3), 256–270. https://doi.org/10.1044/jshd.4703.256

Shriberg, L. D., Lewis, B. A., Tomblin, J. B., McSweeny, J. L., Karlsson, H. B., & Scheer, A. R. (2005). Toward diagnostic and phenotype markers for genetically transmitted speech delays. Journal of speech, language, and hearing research : JSLHR, 48(4), 834–852. https://doi.org/10.1044/1092-4388(2005/058)

Shriberg, L. D., Tomblin, J. B., & McSweeny, J. L. (1999). Prevalence of speech delays in 6-year-old children and comorbidity with language impairment. Journal of speech, language, and hearing research : JSLHR, 42(6), 1461–1481. https://doi.org/10.1044/jslhr.4206.1461

Sitzman, T. J., Mara, C. A., Long, R. E., Jr, Daskalogiannakis, J., Russell, K. A., Mercado, A. M., Hathaway, R. R., Carle, A. C., Semb, G., & Shaw, W. C. (2015). The Americleft Project: Burden of Care from Secondary Surgery. Plastic and reconstructive surgery. Global open, 3(7), e442. https://doi.org/10.1097/GOX.0000000000000415

Stoel-Gammon, C., & Dunn, C. (1985). Normal and Disordered Phonology in Children. University Park Press.

To, C. K. S., McLeod, S., Sam, K. L., & Law, T. (2022). Predicting Which Children Will Normalize Without Intervention for Speech Sound Disorders. Journal of Speech, Language, and Hearing Research, 65(5), 1724–1741. https://doi.org/10.1044/2022_jslhr-21-00444

Trost-Cardamone, J. E.(2012, April). American English Sentence: *A controlled sample for assessing cleft palate speech outcome*. Presented at the Meeting of the American Cleft Palate–Craniofacial Association, San Jose, California, United States.

Waring, R., & Knight, R. (2013). How should children with speech sound disorders be classified? A review and critical evaluation of current classification systems. *International journal of language & communication disorders*, *48*(1), 25–40. https://doi.org/10.1111/j.1460-6984.2012.00195.x

Watson, M. M., & Scukanec, G. P. (1997). Profiling the phonological abilities of 2-year-olds: A longitudinal investigation. *Child Language Teaching and Therapy*, *13*(1), 3–14. https://doi.org/10.1177/026565909701300102

Wolk, L., & Meisler, A. W. (1998). Phonological Assessment: A Systematic Comparison of Conversation and Picture Naming. Journal of Communication Disorders, 31(4), 291–313. https://doi.org/10.1016/s0021-9924(97)00092-0

Wren, Y., Titterington, J., & White, P. (2020). How many words make a sample? Determining the minimum number of word tokens needed in connected speech samples for child speech assessment. *Clinical Linguistics & Phonetics*, *35*(8), 1–18. https://doi.org/10.1080/02699206.2020.1827458

APPENDEIX A

IRB APPROVAL

APPROVAL: MODIFICATION

Nancy Scherer
CHS: Health Solutions, College of
480/496-2905
Nancy.Scherer@asu.edu

Dear Nancy Scherer:

On 9/22/2023 the ASU IRB reviewed the following protocol:

| | |
|---|---|
| Type of Review: | Modification / Update |
| Title: | Validating an automated speech analysis tool for children with cleft lip and/or palate |
| Investigator: | Nancy Scherer |
| IRB ID: | STUDY00016321 |
| Funding: | Name: HHS-NIH: National Institute of Dental & Craniofacial Research (NIDCR), Grant Office ID: AWD00037658, Funding Source ID: DE031253 |
| Grant Title: | None |
| Grant ID: | None |
| Documents Reviewed: | • Consent-Social-Behavioral_Scherer_8.pdf, Category: Consent Form; • IRB Social Behavioral_8.docx, Category: IRB Protocol; • Speech intelligibility questionnaire, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); |

The IRB approved the modification.

When consent is appropriate, you must use final, watermarked versions available under the "Documents" tab in ERA-IRB.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

APPENDEIX B

CLEFT SPEECH ERROR TYPES

| Sound production error category | Examples |
| --- | --- |
| Anterior oral speech errors | |
| Dentalization | /t/ → [ t̪ ] [ t̪͆ ] |
| Lateralization | [ sˡ ] [ ɬ ] |
| Palatalization | [ t ʲ ] [s ʲ ] or [ç ɟ] |
| Mid-dorsum palatal production | Sounds like a mix between /t/ and /k/ or /d/ and /g/ used to substitute for /t, d, k, g/ |
| Bilabial fricatives | Produced at the lips. E.g., [β ɸ] |
| Reversed labiodental placement | |
| Posterior oral speech errors | |
| Double articulation (alveolar with velar) | Simultaneous anterior and posterior production. E.g., [ t͡k] [p͡k] |
| Backed to velar or uvular | /t, d, s, n, l/ backed to velar → [k, g, x, ŋ, L], or backed to uvular → [q, G, χ, N] |
| Non-oral compensatory speech errors | |
| Pharyngeal articulation | Produced when the back of the tongue contacts the pharyngeal wall. E.g., [ħ ʕ] |
| Glottal articulation | Produced using the glottis. E.g., [ʔ] plosive [h ɦ] fricatives |
| Active nasal fricatives | Produced when air is directed into the nasal cavity. E.g., /f/ → [m̥͌] or /s, ʃ, tʃ / → [n̥͌ ŋ̊͌] |
| Glottal co-articulation | Glottal involvement during production — it looks normal but is perceived as partially glottal. E.g., [b͡ʔ] [d͡ʔ] [k͡ʔ] |
| Passive speech errors | |
| Weak or nasalized consonants | Production is weak due to inadequate oral pressure associated with velopharyngeal insufficiency [b̪] [b̃] [d̪] [d̃] |
| Nasal realization of plosives | Nasalized productions due to structural deficit (i.e., obligatory). E.g., /b, d, g/ → [m, n, ŋ] and/or suspected passive nasal fricatives f → [(f͡)m̥], [(f͡)ɱ] or /s / ʃ / → [(s͡)n̥ (x͡)ŋ] |
| Gliding of fricatives or affricates | /f v/ --> [w], /s z ʃ / --> [ j ] |
| Ingressive speech errors | |
| Ingressive oral or nasal fricative | Produced when air is directed inward (i.e., inhalatory production) E.g., Ingressive oral fricatives [s↓] [ʃ↓] [f↓] or nasal fricatives [m̥↓] [n̥↓] |
| Nonpulmonic clicks | Does not require breathing and can be produced by approximating two articulators. E.g., [ʘ ǀ ! ǂ ǁ] |
| Phonological nasal substitutions | |
| Nasal substitution for stop, fricative, affricate, or liquid | Nasal substitution for stop, fricative, affricate, or liquid phoneme that is not judged to be occurring secondary to velopharyngeal insufficiency |

*These categories are derived from the work by John et al. (2006), the Americleft speech project (Chapman et al., 2016), and Lien et al. (2023).

# APPENDIX C

# AMERICAN ENGLISH PHRASE SAMPLE

**American English Phrase Sample[1] – 3yr old Recording Form**

Insert a (✓) for targets correctly produced; transcribe errors in appropriate columns for initial and final positions.

| Target Sentence (targets in bold) | Sound | Initial | Final | Total # Errors |
|---|---|---|---|---|
| 1. **Me** 'n mo**m** | /m/ | | | |
| 2. **P**ull a ro**pe** | /p/ | | | |
| 3. **B**aby bi**b** | /b/ | | | |
| 4. **F**all o**ff** | /f/ | | | |
| 5. **N**ow I wi**n** | /n/ | | | |
| 6. **T**ie a ha**t** | /t/ | | | |
| 7. **D**o it Da**d** | /d/ | | | |
| 8. **S**ee a hou**s**e | /s/ | | | |
| 9. **C**ookie or ca**k**e | /k/ | | | |
| 10. **G**ive a hu**g** | /g/ | | | |
| 11. **H**ow **h**igh!*** | /h/*** | | | |
| 12. **W**e were away | /w/ | | | |
| 13. **V**ery high wa**v**e*** | /v/*** | | | |
| 14. **Th**irty teeth*** | /θ/*** | | | |
| 15. **Th**ere you are!*** | /ð/*** | | | |
| 16. A **l**ow hi**ll** | /l/ | | | |
| 17. A **z**oo i**s** here*** | /z/*** | | | |
| 18. Wa**sh** a **sh**oe*** | /ʃ/*** | | | |
| 19. Wat**ch…**a **ch**oo choo | /tʃ/ | | | |
| 20. **J**oe is hu**ge*** | /dʒ/*** | | | |
| 21. A lo**ng** way*** | /ŋ/*** | | | |
| 22. **Sp**y a **st**ar; spy a **sk**y | /sp/ | | | |
| | /st/ | | | |
| | /sk/ | | | |
| 23. **R**ow you**r** way | /ɹ/*** | | | |
| **TOTAL NUMBER OF CONSONANT ERRORS:** | | | | |
| 24. Man on the moon. | Hyponasality | | | |

[1]Adapted from Trost-Cardamone J. (2012). American English Sentence Sample: A controlled sample for assessing cleft palate speech outcome. Poster, ACPA Annual Meeting, San Jose, CA. (In press) For further information, contact Americleft Speech Group.

^ Items 13-23 contain later developing sounds, administer accordingly.

***Unshared sounds across English and Spanish

# APPENDIX D

## ALL DEVELOPMENTAL/PHONOLOGICAL PROCESSES

| | 3-year-old TD (n=15) Mean (S.D.) | 4-year-old TD (n=15) Mean (S.D.) | 3-year-old Delayed (n=3) Mean (S.D.) | 4-year-old Delayed (n=4) Mean (S.D.) |
|---|---|---|---|---|
| Manner | Deaffrication 0.40 (0.73) | Deaffrication 0.00 (0.00) | Deaffrication 0.33 (0.58) | Deaffrication 0.50 (1.00) |
| | Gliding 6.33 (6.29) | Gliding 3.00 (3.82) | Gliding 5.00 (1.73) | Gliding 8.25 (5.91) |
| | Stopping 2.93 (1.98) | Stopping 1.93 (1.58) | Stopping 7.67 (0.58) | Stopping 2.75 (0.96) |
| | Stridency deletion 1.40 (1.88) | Stridency deletion 0.80 (0.94) | Stridency deletion 13.67 (5.77) | Stridency deletion 1.25 (1.50) |
| | Vocalization 5.27 (5.44) | Vocalization 4.20 (4.66) | Vocalization 10.33 (4.04) | Vocalization 9.50 (3.51) |
| | Affrication 0.40 (0.91) | Affrication 0.00 (0.00) | Affrication 1.00 (1.73) | Affrication 0.00 (0.00) |
| | Frication 0.40 (1.30) | Frication 0.13 (0.52) | Frication 1.00 (1.00) | Frication 0.50 (1.00) |
| | Gliding (Other) 0.27 (0.59) | Gliding (Other) 0.13 (0.52) | Gliding (Other) 2.33 (1.53) | Gliding (Other) 0.00 (0.00) |
| | Liquidization 0.20 (0.41) | Liquidization 0.00 (0.00) | Liquidization 0.00 (0.00) | Liquidization 0.50 (0.58) |
| | Stopping (Other) 0.20 (0.41) | Stopping (Other) 0.13 (0.35) | Stopping (Other) 1.33 (1.53) | Stopping (Other) 0.00 (0.00) |
| Place | Palatal fronting 0.80 (1.66) | Palatal fronting 0.27 (1.03) | Palatal fronting 4.00 (2.00) | Palatal fronting 0.75 (1.50) |
| | Velar fronting 0.40 (0.91) | Velar fronting 0.13 (0.35) | Velar fronting 3.33 (3.21) | Velar fronting 1.25 (1.26) |
| | Backing to velars or /h/ 0.33 (1.05) | Backing to velars or /h/ 0.00 (0.00) | Backing to velars or /h/ 8.67 (7.77) | Backing to velars or /h/ 0.25 (0.50) |
| Reduction | Cluster simplification 3.07 (3.83) | Cluster simplification 0.93 (1.58) | Cluster simplification 18.00 (1.73) | Cluster simplification 2.00 (3.37) |
| | Deletion of final consonant 0.87 (1.25) | Deletion of final consonant 0.67 (0.98) | Deletion of final consonant 7.67 (8.62) | Deletion of final consonant 1.75 (2.36) |
| | Syllable reduction 0.60 (0.74) | Syllable reduction 0.13 (0.35) | Syllable reduction 4.00 (2.00) | Syllable reduction 0.00 (0.00) |

| | | | | |
|---|---|---|---|---|
| | Deletion of initial consonant<br>0.07 (0.26) | Deletion of initial consonant<br>0.00 (0.00) | Deletion of initial consonant<br>2.00 (3.46) | Deletion of initial consonant<br>0.00 (0.00) |
| | Deletion of medial consonant<br>0.07 (0.26) | Deletion of medial consonant<br>0.07 (0.26) | Deletion of medial consonant<br>1.33 (0.58) | Deletion of medial consonant<br>0.00 (0.00) |
| Voicing | Final devoicing<br>1.00 (1.13) | Final devoicing<br>0.33 (0.62) | Final devoicing<br>1.67 (1.53) | Final devoicing<br>1.00 (0.00) |
| | Initial voicing<br>0.20 (0.56) | Initial voicing<br>0.07 (0.26) | Initial voicing<br>0.33 (0.58) | Initial voicing<br>0.50 (0.58) |
| | Initial devoicing<br>1.27 (1.67) | Initial devoicing<br>0.20 (0.41) | Initial devoicing<br>1.00 (1.00) | Initial devoicing<br>0.75 (0.96) |
| | Medial devoicing<br>0.20 (0.56) | Medial devoicing<br>0.13 (0.35) | Medial devoicing<br>0.67 (0.58) | Medial devoicing<br>0.25 (0.50) |
| | Medial voicing<br>0.07 (0.26) | Medial voicing<br>0.27 (0.80) | Medial voicing<br>0.67 (0.58) | Medial voicing<br>0.25 (0.50) |
| Other | Addition<br>0.20 (0.56) | Addition<br>0.13 (0.35) | Addition<br>1.33 (2.31) | Addition<br>1.25 (2.50) |
| | Alveolarization<br>0.47 (0.83) | Alveolarization<br>0.27 (0.46) | Alveolarization<br>3.00 (2.65) | Alveolarization<br>1.50 (1.29) |
| | Coalescence<br>0.07 (0.26) | Coalescence<br>0.00 (0.00) | Coalescence<br>0.33 (0.58) | Coalescence<br>0.00 (0.00) |
| | Interdentalization<br>0.07 (0.26) | Interdentalization<br>0.00 (0.00) | Interdentalization<br>0.33 (0.58) | Interdentalization<br>0.00 (0.00) |
| | Labialization<br>2.60 (2.56) | Labialization<br>0.80 (1.08) | Labialization<br>3.33 (3.21) | Labialization<br>0.0 1.25 (0.96) |
| | Nasalization<br>0.20 (0.41) | Nasalization<br>0.00 (0.00) | Nasalization<br>0.67 (0.58) | Nasalization<br>0.00 (0.00) |
| | Palatalization<br>0.20 (0.77) | Palatalization<br>0.00 (0.00) | Palatalization<br>0.00 (0.00) | Palatalization<br>0.25 (0.50) |
| | Dentalization<br>4.07 (5.24) | Dentalization<br>2.20 (4.49) | Dentalization<br>0.00 (0.00) | Dentalization<br>5.75 (7.14) |
| | Lateralization<br>0.40 (1.30) | Lateralization<br>0.00 (0.00) | Lateralization<br>0.00 (0.00) | Lateralization<br>0.00 (0.00) |
| | Reduplication<br>0.00 (0.00) | Reduplication<br>0.00 (0.00) | Reduplication<br>0.67 (0.58) | Reduplication<br>(0.00) |

Note. Values are presented as the mean number of occurrences with the standard deviation in parentheses