5-2022

Building Speech and Quantifying Complexity: The Manual

Kathy J. Jakielski
Augustana College, Rock Island Illinois, kathyjakielski@augustana.edu

Building Speech & Quantifying Complexity™

THE MANUAL

KATHY J. JAKIELSKI, PH.D., CCC-SLP, ASHA FELLOW

Table of Contents

Preface

Treating disorders of speech, well, it isn't as easy as some people think it is. I first started practicing as a clinical speech-language pathologist almost 40 years ago, and I immediately gravitated toward working with children and adolescents with speech sound disorders because of my firm background in and passion for phonetics. The challenge of applying phonetic science to clinical cases has motivated me throughout my career. I do not believe that we can work effectively with individuals with a speech sound disorder without having a strong background in phonetic science, yet I repeatedly encounter speech-language pathologists who were taught that phonetics begins and ends with phonetic transcription.

These speech-language pathologists find themselves ill-equipped to work with children with challenging speech sound disorders, such as children with childhood apraxia of speech (CAS) and children with few expressive words. Learning how to phonetically transcribe is fundamental to being able to work with children with speech sound disorders, but it is a single skill in a pool of many that are needed. Possessing knowledge of phonetic science is equally as important as possessing transcription skills, yet phonetics too often continues to be taught only as the skill of transcribing.

If you are reading this manual as a speech-language pathologist who feels ill-equipped to work with children with a challenging speech sound disorder, especially a motor speech disorder, then you've come to the right place. In the pages that follow, I provide phonetic science information that you may not have been taught or that you don't remember. Possessing this knowledge can help to increase your clinical effectiveness. Then, by providing you with an approach for how to develop incremental, articulatory-based goals and stimuli, you will be able to systematically increase the demands you place on a child's developing speech system to attain your goals.

Speech is realized by the acquisition of motor skills, and the cognitive-motor learning literature informs us that complex motor skills, which applies to articulation, are developed in an incremental fashion, progressing from more basic to more difficult movements. *Building Speech and Quantifying Complexity (BSQC)* is an approach you can employ that aligns with what we currently understand about skill acquisition. BSQC provides a framework for selecting stimuli in treatment, as well as a tool you can use to assess progress on an ongoing basis to document when and how articulatory change occurs.

My deepest appreciation is extended to everyone who has helped in the development and refinement of the BSQC components over the past 30 years.

The people who contributed most directly include my mentors, Drs. Barbara Davis, Leo Engler, Peter MacNeilage, and Julie Ries; past students I have had the privilege of working with in related research, especially Emily Doyle, Valerie Duncan, Shannon English, Daniel Fogerty, Tania (Egan) Giorgis, Julie Luchessi, Rachel (Matyasse) Wells, Kelly Miller, Kristen Ranta, and Pamela (Ward) Resendiz; clinical colleagues Drs. Dena Granof and Stephanie Jasuta; doctoral students Lisa Mitchell and Anne Van Zelst; and research collaborators Drs. Keven Eldridge, Joan Furey, Shelley Velleman, and Amy Weiss. I also express appreciation to the original publishers of BSQC, Apraxia Kids, previously known as the Childhood Apraxia of Speech Association of North America (CASANA), and Jen Delmonaco at CPI Creative.

The people who contributed most indirectly have included the countless number of children and teens with speech sound disorders with whom I have spent a lifetime working; with their challenges always in mind, I am propelled to ask questions and seek answers every day.

Forever the teacher, I hope that the BSQC approach helps to teach speech-language pathologists how to think as a phonetic scientist when assessing and treating children with speech sound disorders. Forever the student, I hope to learn how we might improve this approach to increase the effectiveness of the clinical services we provide.

Kathy J. Jakielski, Ph.D., CCC-SLP, ASHA Fellow
Professor of Communication Sciences & Disorders
Florence C. and Dr. John E. Wertz Chair in Liberal Arts and Sciences
Augustana College
Rock Island, Illinois

Introduction

Building Speech & Quantifying Complexity (BSQC) is a dual approach to treating and evaluating articulatory complexity in child speech. It has two components: the first is *Building Speech* and the second is *Quantifying Complexity*.

These two components can be used independently or together. When used together, the speech-language pathologist has a method for selecting goals and targets of varying levels of articulatory difficulty, plus a means for measuring changes in a child's words, targeted and produced, at one point in time or over time.

The *Building Speech* component is an approach for increasing a child's ability to produce incrementally more motorically difficult words. Building Speech is appropriate for children with a challenging speech sound disorder and/or a limited number of expressive words, and especially for children diagnosed with the motor speech disorder childhood apraxia of speech. The *Quantifying Complexity* component is a metric, the Index of Phonetic Complexity (IPC), for calculating the articulatory complexity of an individual's word targets and productions.

Building Speech & Quantifying Complexity provides speech-language pathologists with foundational information, so that they can individualize their assessments and interventions to meet the needs of the children on their caseloads with challenging speech sound disorders. It is not intended to be a lock-step program, but rather, an approach to be used creatively and flexibly by speech-language pathologists to address the needs of the individual children on their caseloads.

Building Speech & Quantifying Complexity is designed to assess and treat speakers of American English, although the components can be adapted to fit the phonetics and phonology of other languages.

A Brief Review of Terminology
Used in Building Speech & Quantifying Complexity

The goal of BSQC is to encourage speech-language pathologists to think like a phonetician when planning assessment and treatment. To that end, it is necessary that speech-language pathologists have a working knowledge of the International Phonetic Alphabet, phonetics, and typical speech acquisition. Below is a review of the concepts and terminology that underlie the BSQC approach. A summary of this information can also be found in Appendix A.

Consonant Place Class

Labials: Consonants produced using one or both of the lips
p, b, m, w, f, v

Coronals: Consonants produced with the tongue tip on or near the alveolar ridge
t, d, n, j, θ, ð, s, z, ʃ, ʒ, t͡ʃ, d͡ʒ, l, ɹ

Dorsals: Consonants produced with the tongue body at the velum
k, g, ŋ

Glottals: Consonants produced at the level of the vocal folds, without supralaryngeal articulation
ʔ, h

Consonant Manner Class

Stops: p, b, t, d, k, g, ʔ

Nasals: m, n, ŋ

Glides: w, j

Fricatives: f, v, θ, ð, s, z, ʃ, ʒ, h

Affricates: t͡ʃ, d͡ʒ

Liquids: l, ɹ

Vowel Manner Class

Monophthongs
i, ɪ, e, ɛ, æ, ʌ/ə, u, ʊ, o, ɔ, ɑ

Diphthongs
Phonemic: a͡ɪ, a͡ʊ, ɔ͡ɪ
Non-phonemic: e͡ɪ, o͡ʊ

Rhotics
ɚ, ɪ͡ɚ, ɛ͡ɚ, u͡ɚ, ɔ͡ɚ, ɑ͡ɚ, a͡ɪɚ, a͡ʊɚ

Consonant and Vowel Places of Articulation

Homorganic: Speech sounds produced in the same place of articulation.

Homorganic Consonants

labial - labial: p-m, b-w, etc.

coronal - coronal: t-n, ʃ-l, etc.

dorsal - dorsal: k-g, g-ŋ, etc.

Homorganic Clusters

labial + labial: pw, bw, etc.

coronal + coronal: st, sn, etc.

dorsal + dorsal: ŋk, ŋg

Homorganic C + V

coronal consonants + front vowels

t, d, n, j, s, z, ʃ, t͡ʃ, d͡ʒ, l + i, ɪ, e, ɛ, æ

dorsal consonants + back vowels

k, g, ŋ + u, ʊ, o, ɔ, ɑ

Heterorganic: Speech sounds produced in different articulatory places

Phonotactic Structure

Open Word Shapes: Words ending with a vowel, such as V, CV, CVCV, CCV, CVCVCV, etc.

Closed Word Shapes: Words ending with a consonant, such as VC, CVC, CVCVC, CCVC, CVCC, etc.

Reduplications

$C_1V_1C_1V_1$, $C_1V_1C_1V_1C_1V_1$, etc.

Variegations

$C_1V_1C_2V_1$, $C_1V_1C_1V_2$, $C_1V_1C_2V_2$, etc.

Building Speech™:
Eight Steps for Increasing Articulatory Complexity

Building Speech is an approach for selecting goals and constructing targets in speech intervention based on articulatory movements and movement sequences that progress from basic to more complex. Building Speech is based on the premise that children with challenging speech disorders benefit from intervention that begins by teaching the child how to articulate words and phrases constructed of speech movement patterns that follow the early acquisition exhibited by typically-developing children. Those basic speech movement patterns serve as “frames” for the child’s later productions of more complex articulations.

Building Speech consists of eight speech frames that progress from basic to more complex, as well as suggestions for the early “content” (i.e., the speech sounds) to insert into each frame. Consider the speech sounds recommended for each speech frame as a potential starting point. Once those frames and the suggested sounds are acquired, later-developing sounds can be inserted into the frames to increase articulatory difficulty, thereby increasing their functionality.

The eight speech movement patterns in *Building Speech* broadly follow patterns typical in babbling and early speech development. These general early patterns include child mastery of:

- Stops, nasals, and glides prior to fricatives, affricates, and liquids
- Monophthongs prior to diphthongs and diphthongs prior to rhotics
- Open word shapes prior to closed word shapes
- Reduplicated syllables prior to variegated syllables
- Homorganic consonant + vowel sequences and homorganic consonant + consonant sequences prior to heterorganic construction
- Voiced consonants in word-initial position prior to voiced consonants in word-final position
- Voiceless consonants in word-final position prior to voiceless consonants in word-initial position

The Eight Building Speech Patterns

A list of words and phrases for each of the eight frames can be found in Appendices B-I.

Pattern 1: CV

Consonants are voiced stops and nasals. Vowels are monophthongs and diphthongs.

Stimuli in Pattern 1 are selected by constructing words that have a consonant + vowel shape. The consonants to be targeted include the voiced stops /b, d, g/ and the monophthong and diphthong vowels / i, ɪ, e, ɛ, æ, ʌ/ə, u, ʊ, o, ɔ, ɑ, a͡ɪ, a͡ʊ, ɔ͡ɪ/. The consonant + vowel combinations can be either homorganic or heterorganic.

Examples include bee, bye, day, go, moo, and no.

Pattern 2: C_1V_1 + C_1V_1

Disyllabic words containing reduplicated syllables or words from Pattern 1 repeated.

Stimuli in Pattern 2 are selected from words with reduplicated syllables containing voiced stops and nasals or by having the child sequentially repeat the words in Pattern 1 two times each.

Examples include bee-bee, bye-bye, dada, day-day, go-go, mama, moo-moo, and no-no.

Pattern 3: $C_{hom}VC_{hom}V$

Consonants are homorganic and the word shape is open.

Stimuli in Pattern 3 are selected by constructing disyllabic words and phrases that have a shape of CVCV and contain homorganic consonants; any consonant can be paired with any vowel. Consonants can be grouped into four broad places of articulation: labial, coronal, dorsal, and glottal. Labial consonants include bilabials and labiodentals (/p, b, m, w, f, v/). Coronal consonants include interdentals, alveolars, post-alveolars, alveopalatals, and palatals (/θ, ð, t, d, n, s, z, l, ʃ, ʒ, t͡ʃ, d͡ʒ, j, ɹ/. Dorsal consonants include velars (/k, g, ŋ/). Glottal consonants include stop /ʔ/ and fricative /h/.

Examples include maybe, my boy, go cow, ha-ha, and uh-oh.

Pattern 4: $C_{hom}VC_{hom}VC_{hom}$
Consonants are homorganic and the word shape is closed.

Like Pattern 3, stimuli in Pattern 4 are selected by constructing disyllabic words and phrases with homorganic consonants; however, in Pattern 4, stimuli have a closed word shape CVCVC.

Examples include my pup, new doll, and kicking.

Pattern 5: $C_{het}VC_{het}V$
Consonants are heterorganic and the word shape is open.

Stimuli in Pattern 5 are selected by constructing disyllabic words and phrases that have a shape of CVCV and contain heterorganic consonants. Any consonant can be paired with any vowel, preferably begin using consonants and vowels already in the child's phonetic inventory. As with Patterns 3 and 4, continue to think broadly about consonant place of articulation, categorizing sounds by only four places of articulation: labial, coronal, dorsal, and glottal.

The possible heterorganic consonant combinations include labial-coronal, labial-dorsal, labial-glottal, coronal-labial, coronal-dorsal, coronal-glottal, dorsal-labial, dorsal-coronal, dorsal-glottal, glottal-labial, glottal-coronal, and glottal-dorsal. Note that the production of word-medial /ʔ/ is dialectal and usage ranges from rare to frequent.

Examples include gimme, my toe, and hey boy.

Pattern 6: $C_{vd}VC_{nas}$
Initial consonants are voiced stops, nasals, glides, or fricatives. Final consonants are nasals.

Stimuli in Pattern 6 are selected by constructing monosyllabic words that begin with a voiced stop, nasal, glide, or fricative (/b, d, g, m, n, w, j, v, ð, z, ʒ/) and end with a nasal (/m, n, ŋ/).

Examples include boom, done, game, gum, gone, and mom.

Pattern 7: $C_{vd}VC_{vl}$

Initial consonants are voiced stops, nasals, glides, or fricatives. Final consonants are voiceless stops or fricatives.

Stimuli in Pattern 7 are selected by constructing monosyllabic words that begin with a voiced stop, nasal, glide, or fricative (/b, d, g, m, n, w, j, v, ð, z, ʒ/) and end with a voiceless stop or fricative (/p, t, k, f, θ, s, ʃ/).

Examples include bat, mop, moose, nap, and wish.

Pattern 8: CV + CV(C)

The first syllable varies. The second syllable remains the same.

Stimuli in Pattern 8 are selected by constructing CVCV(C) disyllabic words in which the second syllable remains the same phonetically; therefore, all the words in one set will have the same final syllable.

Examples include "knee words," such as, bunny and shiny; "bull words," such as, table and gobble; and "D (dee) words," such as, teddy and daddy.

Getting Started

To begin using the *Building Speech* approach, speech-language pathologists need to have an understanding and a working knowledge of the terms and concepts that are foundational to the BSQC approach. A review of this information can be found in Appendix A.

Speech-language pathologists begin intervention only after analyzing a representative speech sample from a child suspected of having a speech sound disorder. After gathering a conversation speech sample, speech-language pathologists want to phonetically transcribe each word in the sample and analyze the speech movement patterns in the child's productions to not only determine the sounds and sound sequences that are misarticulated, but to also determine the sounds and sound sequences that the child produces correctly. The latter information is critical, as it provides speech-language pathologists with the articulatory starting place for intervention.

Building Speech is an approach for selecting the words to target in intervention; it does not prescribe how to teach the production of the words. Speech-language pathologists can use a variety of methods to elicit correction productions; however, as a phonetic-based approach itself, *Building Speech* is most compatible with motor-based approaches such as Dynamic Temporal and Tactile Cueing (DTTC; Strand, 2020); PROMPT (Dale & Hayden, 2013); visual biofeedback, such as ultrasound (e.g., Preston, Maas, Whittle, Leece, & McCabe, 2016); and other articulation-based therapies. Those methods are used to elicit correct articulations, while *Building Speech* is used to determine the words to target in intervention.

The focus should be on targeting the speech frame itself as the goal. *Building Speech* provides eight frames, specific speech sounds for each frame, and subsequent word and phrase stimuli for each frame. The eight frames serve as speech intervention goals, replacing or supplementing more traditional goals targeting specific speech sounds.

In other words, the actual speech goal can be mastery of a particular speech movement pattern, as opposed to a specific sound. For example, one goal could be for the child to correctly produce functional CV words containing word-initial voiced stops and nasals combined with monophthong vowels, and another goal could be for the child to correctly produce functional CVCV words containing homorganic consonants.

Begin to incorporate *Building Speech* stimuli into your intervention by targeting the earliest speech sequences that are difficult for the child to produce. For example, if the child already correctly articulates a variety of words using Patterns 1, 2, and 3, then begin intervention by targeting words in Pattern 4. Or, if the child does not show mastery of any of the patterns, then begin by targeting Pattern 1 words.

Refer to the eight patterns in *Building Speech* to help you think about movement patterns in a hierarchical manner, but be aware that not all children, especially those with childhood apraxia of speech, follow the typical acquisition sequence. Be prepared to rearrange the sequence of speech frames to fit each child's phonetic and phonological repertoires.

The approach of *Building Speech* is to incrementally build motor speech capability from the bottom up, while engaging the child in functional communication tasks using real words.

Frequently Asked Questions

1. Why is Building Speech referred to as an intervention approach, as opposed to an intervention program?

Building Speech is not intended to be used as a single-step-by-single-step program. Instead, it is a method for developing speech targets of increasing articulatory complexity. It is designed to be flexible and adapted as necessary for individual children. Speech-language pathologists are encouraged to use their own knowledge of phonetics and phonology to modify the patterns and/or stimuli as needed.

---

2. Who can benefit from the Building Speech approach?

Building Speech was originally developed for children with CAS; however, children with other types of articulation disorders and very limited expressive vocabulary may benefit from an incremental increase in articulatory complexity. Speech is, in part, a motor skill, and *Building Speech* was developed using motor learning principles; therefore, it is also appropriate to use with other children with challenging speech sound disorders.

---

3. How do I analyze a child's speech to maximize success using the Building Speech intervention approach?

In addition to determining the sound errors exhibited by a child, you will also need to derive a phonetic inventory. A phonetic inventory is a list of all the consonants, vowels, and word shapes the child produced—even if a production was not the target. For example, if a child said /dət/ for /ɹək/, then the child's phonetic inventory would contain word-initial /d/, word-final /t/, vowel /ə/, and word shape CVC. These consonants, vowels, and word shapes are the raw speech skills the child already possesses, and you will use those structures to gradually build more complex phonological structures. This idea is fundamental to the *Building Speech* approach—begin intervention from a base of articulatory skill, and then incrementally increase the difficulty. A speech-language pathologist knows a child's base of articulatory skill by deriving a phonetic inventory.

---

4. How do I use a child's phonetic inventory in the Building Speech approach?

After you have selected the *Building Speech* patterns you want to target in intervention, use as many of the consonants and vowels that are already in the child's phonetic inventory that you can to build target words that fit the patterns you selected—even if the sounds the child produces are different than the sounds suggested for the pattern.

In this way, you are targeting new speech frames using sounds the child already produces correctly (at least some of the time) (e.g., see Leonard, Schwartz, Morris, & Chapman, 1981; Schwartz & Leonard, 1982). Therefore, you are targeting the frame only, as opposed to the frame and the speech sound content.

Targeting both simultaneously can be exceptionally difficult for a child with a challenging speech sound disorder, so you want to minimize the articulatory difficulty as much as possible. In the same way, when you select a new sound to target, use a pattern that is already in the child's phonetic inventory, so that you are not targeting both a new speech frame and the new speech sound.

5. Do I always start with Pattern 1?

No, not necessarily. Children with a limited expressive vocabulary will most likely benefit most significantly from Patterns 1-4, because those patterns are based on the earliest vocal and verbal acquisition data. It is suggested that the early patterns be targeted first in children with the most severe speech sound disorders, or in children who have very few expressive words. In such cases, even these early patterns may need modifications. For example, even though Patterns 1-4 do not specify constructing homorganic consonant + vowel sequences, keeping consonant and vowel place of articulation the same may increase a child's ability to imitate targets.

6. Do I have to follow the eight patterns in sequence?

While the *Building Speech* patterns are proposed to be in a general order of increasing difficulty, the order of the patterns is not fixed, so experiment to find the pattern(s) that can be used to address a child's particular needs most successfully and efficiently.

7. What if a child gets "stuck" on one pattern?

When a child exhibits difficulty on a particular pattern, be certain to evaluate the consonant and vowel sequences in your target words, and then experiment with changing the sounds in the words as necessary to obtain at least entry-level success. In addition, be willing to create new frames that serve as a bridge to the next movement sequence. For example, some master clinicians have reported that they have had children with CAS who experienced significant difficulty moving from Pattern 2 (C1V1 + C1V1) to Pattern 3 (ChomVChomV), so they developed an intermediate VC frame.

Many functional words fit the VC frame, including eat, ate, eight, in, on, off, up, etc., and these speech-language pathologists have reported success moving to Pattern 3 words only after teaching their children how to master this intermediate “Pattern 2.5” speech frame. It is this type of thinking and problem solving that is encouraged when using the *Building Speech* approach!

---

8. Why is there so much flexibility in using the Building Speech approach?

There are so many factors to keep in mind when selecting words to target in intervention that it would be mistaken to think that any approach or program could cover all of them. For example, not all within-class sounds are mastered at the same time; the velar stops /k, g/ are typically mastered after the bilabial and alveolar stops are mastered. Developing a treatment approach that addresses every nuance would result in a very cumbersome approach. Speech-language pathologists need to use their knowledge and judgment when selecting the consonants and vowels to develop target words and phrases. In addition, children with challenging speech sound disorders are a heterogeneous group that requires flexibility and individualized decision-making.

Remember also that speech acquisition in children with challenging speech sound disorders might not always mirror typical acquisition patterns, so speech-language pathologists need to be willing to re-sequence the patterns as necessary. For example, a child may exhibit the later-mastered sound /l/ in words, but not have mastered /p/. In such cases, target words with /l/ before targeting words with /p/. Always base intervention decisions on a child’s individual phonetic and error repertoires.

---

9. There are a lot of words suggested for each pattern, how do I decide which ones to target?

Focus intervention using words and phrases that are meaningful to the child in front of you. Keep in mind that the goal is to increase the child’s communicative power. To increase communicative power, speech-language pathologists will need to select and develop words and phrases that are functional for each child.

10. How can I determine which words are functional for a particular child?

To determine functional words to target, speech-language pathologists will need to select child-specific vocabulary. A valuable resource for obtaining a comprehensive list of functional, child-specific vocabulary for English and Spanish learners is the Functional Communication Parent Questionnaire (FCPQ; https://sites.google.com/pdx.edu/mabslab/resources). The FCPQ is a survey of words important to a particular child that is completed typically by a child's caregiver. Teachers also are an excellent source for vocabulary that is important in the classroom and school settings.

There will be many times, however, when a speech frame itself is important to articulatory complexity, but the target words for that frame are limited in number or are not particularly functional for a particular child. In these cases, be creative and imbue those target words with meaning. Construct activities and games that create meaningful contexts in which to target those words in authentic communicative interactions. Similarly, if there are words or phrases in the stimuli sets that do not hold meaning for a particular child, then omit those examples.

---

11. Can I make up my own words to fit the patterns?

Speech-language pathologists are encouraged to do so! The stimuli included in Building Speech are examples, and far from an exhaustive list of target possibilities. For example, many proper names fit the *Building Speech* patterns; however, only a few names are included as examples. Select and create speech targets that can be taught in intervention.

Overall, do not be limited by the words and phrases provided in the *Building Speech* stimuli sets. Whenever possible, build additional words and phrases that have meaning for a child using any of the patterns, and then create your own stimuli and activities to provide authentic practice opportunities.

---

12. What about developing nonsense words to practice in intervention?

Speech-language pathologists may consider developing nonsense strings of consonants and vowels to fit a particular pattern when there is a limited number of words and phrases that fit a pattern or when it's deemed important to work on particular consonants and vowels within a particular pattern. In these cases, be cognizant that teaching these movement sequences are not communicatively functional, so use this strategy thoughtfully.

13. I have a child on my caseload whose CAS is severe; can I target sound approximations in Building Speech?

Children with motor speech disorders such as CAS may imprecisely produce a target consonant or vowel sound. Speech-language pathologists will need to consider whether approximations or compensations for those sounds for either a temporary or permanent period will be acceptable or not. While a fully accurate production is desirable, it may not always be a practical goal for a child with a severe speech sound disorder. If, however, you believe that the child will eventually be able to produce the sound, then target the actual sound and not an approximation.

14. Given that English has different types of diphthong vowels and given that some children with CAS have difficulty acquiring diphthong vowels, how should we target diphthongs?

Two monophthong vowels can be classified as non-phonemic diphthongs in American English: /e͡ɪ/ and /o͡ʊ/. Speech-language pathologists can teach these productions as either monophthongs or diphthongs, because changing the production will not change the meaning of the word. However, teaching these vowels as monophthongs may lead to faster success, given that diphthong vowels require rapid movement of the tongue from one place to another.

15. Why do some of the target words in Pattern 5 end in a consonant when the speech frame is an open syllable?

Some of the stimuli provided in Building Speech are words containing a post-vocalic /l/ (written in parentheses), even though the particular pattern does not target a consonant in word-final position. Because these stimuli can be produced with a dark /l/ sound, the child does not need to produce an idealized /l/ (i.e., with the tongue tip at the alveolar ridge) for the word to be intelligible; therefore, they are included as possible word targets. Other examples are included to expand the number of words you can target, although the final consonant will be modeled, but not produced by the child.

Quantifying Complexity™:
Eight Steps for Calculating Articulatory Complexity in Children

The Index of Phonetic Complexity (IPC) is a metric developed to assess the production difficulty of different speech sounds, syllables, and words. The IPC is designed to quantify the articulatory complexity of the words children target and produce. The IPC is a modification of the Index of Cluster Complexity (Jakielski, 1998) that was derived from the early work of MacNeilage and Davis (1990) and their subsequent research (e.g., Davis & MacNeilage, 1995), as well as others' research on early speech acquisition (e.g., Schwartz, Leonard, Loeb, & Swanson, 1987; Stoel-Gammon & Cooper, 1984; Stoel-Gammon, 1987; Vihman, Ferguson, & Elbert, 1986).

The IPC Scoring System

The IPC contains eight indices that are based on the concept of ease of articulation, as displayed in the following table. The eight indices include: 1) consonant place class, 2) consonant manner class, 3) vowel manner class, 4) word shape, 5) word length in number of syllables, 6) place variegation of singleton consonants, 7) contiguous consonants, and 8) place variegation of contiguous consonants.

An IPC value can be calculated for any target or produced word. To derive an IPC value, a word is assigned complexity points (0 or 1) indicating its articulatory difficulty across the eight indices. The complexity points for each word then are summed to derive the word's IPC value. The higher the IPC value, the higher the word's articulatory complexity is purported to be. A child's mean IPC value can be derived by dividing the sum of all the IPC values by the total number of words analyzed.

Index of Phonetic Complexity: Scoring System

Indices	Points Assigned for:	No Points for a:	One Point for Each:
1	consonants by place class	labial coronal glottal	dorsal
2	consonants by manner class	stop nasal glide	fricative affricate liquid
3	vowels by class	monophthong diphthong	rhotic
4	word shape	word that ends with a vowel	word that ends with a consonant
5	word length in syllables	monosyllabic or disyllabic word	three- (or more) syllable word
6	singleton consonants by place variegation	word with place reduplicated singletons	time consecutive singleton consonants vary by place
7	contiguous consonants	word without a cluster	consonant cluster
8	cluster by type	homorganic cluster	heterorganic cluster

Characteristics in the IPC that receive a complexity point of zero (0) generally are earlier-mastered sounds, sound combinations, and word shapes. Characteristics that receive no complexity points include labials, coronals, and glottals; stops, nasals, and glides; monophthongs and diphthongs; open word shapes; mono- and di-syllabic words; homorganic singleton consonants; words with no consonant clusters; and homorganic consonant clusters.

Characteristics that each receive one complexity point generally are later-mastered sounds, sound combinations, and word shapes. Characteristics that receive 1 point each include dorsals; fricatives, affricates, and liquids; rhotics; a closed word shape; a tri+-syllabic word; heterorganic singleton consonants; consonant clusters; and heterorganic consonant clusters.

IPC Terminology

It is important to define the terms used in the IPC because terminology varies across geographical regions and practitioners. Again, a review of terminology can be found in Appendix A. Approximately seven place classifications typically are used to describe where in the vocal tract speech sounds in English are produced (e.g., bilabial, labiodental, interdental, etc.); however, these narrow classifications also can be collapsed into four larger divisions of the vocal tract, including labial (i.e., sounds produced using one or both lips), coronal (i.e., sounds produced near or on the alveolar ridge), dorsal (i.e., sounds produced in the back of the mouth), and glottal (i.e., sounds produced by the vocal folds only).

Likewise, there are different consonant manner classifications that can used to describe how speech sounds are produced. In the IPC, six manner classes are used to capture typical acquisition data, including stops, nasals, glides, fricatives, affricates, and liquids. The IPC uses three primary vowel categories, including monophthongs (i.e., vowels produced using a single tongue gesture), diphthongs (i.e., vowels produced using two rapidly-articulated tongue gestures in a single sound), and rhotics (i.e., vowels preceding /ɹ/ in a single syllable, creating a vowel with r-coloring).

In the IPC, word shapes are described as open or closed, depending on whether the word ends with a vowel or a consonant, respectively. For example, the word “okay,” produced /o.ke/, has a vowel-consonant-vowel (VCV) word shape that is called open because the word ends with a vowel sound.

Alternately, the word “cat,” produced /kæt/, has a consonant-vowel-consonant (CVC) word shape that is called closed because “cat” ends in a consonant sound.

Word length in the IPC is measured by counting the number of syllables in a word. The number of syllables can be determined by counting the number of vowels and syllabic consonants in a word, with each vowel or syllabic consonant designating one syllable. For example, the word “cat,” produced /kæt/, has only one vowel, /æ/, so it is a one-syllable word. The word “kittycat,” produced /kɪ.ɾi.kæt/, has three vowels, /ɪ/, /i/, and /æ/, so it is a three-syllable word.

Place variegation can be computed only when a word contains two or more successive singleton consonants. For example, place variegation can be counted in the word “tulip” (/tu.lɪp/) because there are three successive singleton consonants: /t/ (a coronal) → /l/ (a coronal) → /p/ (a labial). The word “tulip” has the potential for up to two points as consonant articulations move from /t/ to /l/ and then /l/ to /p/. In the first movement, from coronal /t/ to coronal /l/, no point is awarded because place of consonant articulation does not vary. In the second movement, from coronal /l/ to labial /p/, 1 point is awarded for heterorganicity because place of articulation varies. Therefore, only 1 point is awarded to tulip for singleton consonant variegation.

Alternately, place variegation cannot be computed in the word “monkey” (/məŋ.ki/), because it contains only one singleton consonant, /m/ (along with one word-medial cluster, /ŋk/). Similarly, place variegation cannot be computed in the word “chimp” because there is only one singleton consonant, /t͡ʃ/, along with one word-final cluster /mp/.

In the IPC, all contiguous consonants produced in a word are consonant clusters; therefore, clusters can occur in word-initial, -medial, and -final positions. For example, in the word “skip” there is a word-initial /sk/ cluster, in the word “basket” there is a word-medial /sk/ cluster, and in the word “mask” there is a word-final /sk/ cluster. Consonant clusters are homorganic if all the segments in the cluster are produced in the same place of articulation, as designated by labial, coronal, dorsal, and glottal. For example, the /st/ cluster contains two coronal consonants, so /st/ is designated as a homorganic cluster. Clusters are heterorganic if the place of articulation varies among cluster segments. The /sk/ cluster in the word “skip,” for example, contains the coronal consonant /s/ followed by the dorsal consonant /k/, which results in a heterorganic cluster.

Calculating Articulatory Complexity Using the IPC

Once utterances are phonetically transcribed, you can start computing the complexity of each word. You can compute values for target forms (T-IPC) or actual productions (P-IPC). You may enter the data right into a spreadsheet. Appendix J displays an example of a T-IPC Data Form and Appendix K displays an example of a P-IPC Data Form.

When computing complexity points, you may find it easiest to focus on computing one indicator at a time across all of the words in your sample, as opposed to calculating all eight indices in one word before moving to the next word.

We will use the word “ladybugs” /le.di.bəgz/ for our example of how to count.

1. Place: Each *dorsal* (abbreviated as D on the Data Forms) gets **1 point**. There is one dorsal in our example, /g/, so “place” gets **1 point**.

2. Manner: Each *fricative*, *affricate*, and *liquid* (FAL) gets **1 point**. There is one fricative, /z/, and one liquid, /l/, so we score **2 points** for consonant manner.

3. Vowels: Each *rhotic* vowel (R) gets one point. There are no rhotic vowels in our example, so **0 points**.

4. Word Shape: If the word ends with a consonant (FC), then it gets 1 point, so our example gets **1 point** for being a closed word shape.

5. Word Length in Syllables: Words with three or more syllables (3+) get 1 point. Our example has three syllables, so it gets **1 point** for this indicator.

6. Singleton Place Variegation: If a word has singleton consonants that are *place variegated* (SPV), then the word gets 1 point each time place is varied from singleton consonant to singleton consonant. (Note, do not count variegation if one of the consonants is included in a cluster; cluster place variegation is accounted for later.) In the word “ladybugs” (/le.di.bəgz/), we have three singleton consonants. We move from coronal /l/ to coronal /d/ (0 points) to labial /b/ (1 point). The place variegation of coronal to labial scores **1 point** for the word.

7. Contiguous Consonants: Each *cluster* (CC) gets 1 point, no matter how many consonants comprise the cluster (e.g., /st/ would get 1 point; likewise, /str/ also would get 1 point). Clusters are any consonants produced consecutively, even if they cross syllable boundaries. (So in the IPC, “pizza” /pit.sə/, for example, would get 1 cluster point, even though /t/ and /s/ are in different syllables.) Our example “ladybugs” contains the word-final cluster /gz/, so we score **1 point**.

8. Cluster Type: If the consonants comprising a cluster vary in place (CCV), then it is *heterorganic*. The /gz/ cluster in our example moves from the dorsal /g / to the coronal /z/; therefore, we score **1 point** for “cluster type.”

9. A Word’s Total IPC Value: Now add the number of points that you scored for each of the IPC indices. Computing our example, we find that /le.di.bəgz/ has an IPC value of **8 points**.

10. Additional Analyses: Once you’ve computed IPC values for all the words in your speech sample, you then can calculate mean and standard deviation, as well as complete a factor analysis to determine specific information regarding the eight complexity indices. You can graph the IPC values over time to visually see changes in a child’s articulatory skills, as well as compare how T-IPC and P-IPC values compare over time.

Practice Computing IPC Values

Word: /mɑ.mi/

The target word “mommy” contains no later-mastered: place class consonants (i.e., velars), manner class consonants (i.e., fricatives, affricates, liquids), rhotic vowels, final consonant, three or more syllables, heterorganic singleton consonants, or clusters. Therefore, the word “mommy” has an **IPC value of 0**.

Word: /dɔg/

The target word “dog” contains one velar consonant and one final consonant, and requires one singleton consonant place variegation; therefore, this word receives an **IPC value of 3**.

Word: /dɔ.gi/

The target word “doggy” contains one velar and requires one singleton consonant place variegation; therefore, this word receives an **IPC value of 2**, while the indicators contributing to the IPC value are different than for the word “dog.”

Word: /bɑ.ɾʊl/

The target word “bottle” (/bɑ.ɾʊl/) contains no velars, so it receives 0 for consonant place class. It does not contain any fricatives or liquids; however, it does contain one liquid (i.e., /l/), so it receives 1 point for consonant manner class. There are no rhotics, so no point for vowel manner class. There is a final consonant, so it receives 1 point for a closed word shape. No point is awarded for word length because it doesn’t have three or more syllables. There are three singleton consonants, /b/, which is a labial; tap /ɾ/, which is a coronal; and /l/, which also is a coronal.

Therefore, the articulators vary in place when moving from /b/ to /ɾ/, earning 1 point, but moving from /ɾ/ to /l/ is not place varied, so a total of 1 point for singleton variegation. There are no clusters in this word, so no points for the last two indices. Adding all the complexity points (1 for manner class, 1 for closed word shape, 1 for singleton place variegation), we find that the target word “bottle” has an **IPC value of 3**.

Word: /spə.gɛ.ɾi/

The target word "spaghetti" (/spə.gɛ.ɾi/) contains one velar, so it receives 1 for consonant place class. It contains one fricative /s/, but no affricates or liquids, so it receives 1 point for consonant manner class. There are no rhotics, so no points for vowel manner class. It ends in a vowel sound, so it receives no points because it has an open word shape. It has three vowels, /ə/, /ɛ/, and /i/, so it is three syllables long; therefore, 1 point is awarded for word length. There are two singleton consonants, /g/, which is a dorsal, and tap /ɾ/, which is a coronal; therefore, the articulators vary from dorsal to coronal places, earning 1 point for singleton variegation.

There is one cluster in this word, /sp/, so 1 point for contiguous consonants. The /sp/ cluster is heterorganic because the articulators move from a coronal position for /s/ to a labial position for /p/. Adding all the complexity points (1 for place class, 1 for manner class, 1 for word length, 1 for singleton place variegation, 1 for cluster, and 1 for heterorganic cluster), we find that the target word "spaghetti" has an **IPC value of 6**.

Additional Practice

Try to score the following words without looking at the scores provided, and then compare your point allocations and totals to those listed.

Target Word	Phonetic Transcription	Number of Complexity Points: Indicator # (Associated # of Points)	IPC Value
daddy	dæ.di		0
bib	bɪb	4 (1)	1
pizza	pit.sə	2 (1), 7 (1)	2
coat	kot	1 (1), 4 (1), 6 (1)	3
tomato	tə.me.ɾo	5 (1), 6 (2)	3
pjs	pi.d͡ʒez	2 (2), 4 (1), 5 (1)	4
dandelion	dæn.də.la͡ɪ.ən	2 (1), 4 (1), 5 (1), 7 (1)	4
umbrella	əm.brɛ.lə	2 (2), 5 (1), 7 (1), 8 (1)	5
alligator	æ.lɪ.ge.ɾɚ	1 (1), 2 (1), 3 (1), 5 (1), 6 (2)	6
pajamas	pə.d͡ʒɑ.məz	2 (2), 4 (1), 5 (1), 6 (3)	7

Appendix A
Terminology

Consonants: Place Classifications

labials: p b m w f v

coronals: θ ð t d ɾ n s z j ʃ ʒ t͡ʃ d͡ʒ l ɹ

dorsals: k g ŋ

glottals: ʔ h

Consonants: Manner Classifications

stops: p b t d ɾ k g ʔ

nasals: m n ŋ

glides: w j

fricatives: f v θ ð s z ʃ ʒ h

affricates: t͡ʃ d͡ʒ

liquids: l ɹ

Vowels: Manner Classifications

monophthongs: i ɪ e ɛ æ ə u ʊ o ɔ ɑ

(phonemic) diphthongs: a͡ɪ a͡ʊ ɔ͡ɪ

rhotics: ɚ ɪ͡ɚ ɛ͡ɚ u͡ɚ ɔ͡ɚ ɑ͡ɚ aɪ͡ɚ aʊ͡ɚ

Phonotactic Structure

- A word ending with a consonant = closed
- A word ending with a vowel = open

Syllable Structure

- Every vowel denotes a separate syllable
- A vowel = a syllable (consonants are optional)

Singleton Consonant Variegation

If place varies when moving from one single consonant to the next singleton, then considered “variegated;” each variegation = 1 point

Contiguous Consonants Variegation

- Contiguous consonants = “a consonant cluster”
- A cluster is “heterorganic” when place differs among its segments

Appendix B
Stimuli for Pattern 1: CV Voiced Stops & Nasals

Consonants are voiced stops and nasals. Vowels are monophthongs and diphthongs.

Stimuli in Pattern 1 are selected by constructing words that have a consonant + vowel shape. The consonants to be targeted include the voiced stops /b, d, g/ and the monophthong and diphthong vowels /i, ɪ, e, ɛ, æ, ə, u, ʊ, o, ɔ, ɑ, a͡ɪ, a͡ʊ, ɔ͡ɪ/. The consonant + vowel combinations can be either homorganic or heterorganic.

stops

bee	bough	do/dew
bay	boy	dough
boo	D	dye
bow	day	goo
bye	duh	go
bow		guy

nasals

me	mow	neigh
may	my	new
ma	knee	no
moo		now

Appendix C
Stimuli for Pattern 2: $C_1V_1 + C_1V_1$ Reduplicated Words

Disyllabic words containing reduplicated syllables or words from Pattern 1 repeated.

Stimuli in Pattern 2 are selected from words with reduplicated syllables containing voiced stops and nasals or by having the child sequentially repeat the words in Pattern 1 two times each.

stops

bee-bee	bough-bough	do-do
bay-bay	boy-boy	dough-dough
boo-boo	D-D	dye-dye
bow-bow	dada	goo-goo
bye-bye	day-day	go-go
bow-bow	duh-duh	guy-guy

nasals

me-me	mow-mow	neigh-neigh
may-may	my-my	new-new
mama	knee-knee	no-no
moo-moo		now-now

Appendix D
Stimuli for Pattern 3: $C_{hom}VC_{hom}V$ Homorganic Consonants in an Open Word Shape (Including CV words repeated twice)

Consonants are homorganic and the word shape is open.

Stimuli in Pattern 3 are selected by constructing disyllabic words and phrases that have a shape of CVCV and contain homorganic consonants; any consonant can be paired with any vowel. Consonants can be grouped into four broad places of articulation: labial, coronal, dorsal, and glottal. Labial consonants include bilabials (/p, b, m, w/). Coronal consonants include interdentals, alveolars, palatals, and alveopalatals (/θ, ð, t, d, n, s, z, l, ɹ, j, ʃ, ʒ, t͡ʃ, d͡ʒ/). Dorsal consonants include velars (/k, g, ŋ/). Glottal consonants include stop /ʔ/ and fricative /h/.

labials

words

p peepee, papa, pawpaw, people, PB, peewee, puma, pow-wow
b BB, BP, baby, beeper, Bobby, bobber, bye-bye
m mama, maybe, Moby
w whee-whee, weepy

phrases

bye	+	________	pea, pay, pa, paw, pie, purr
boy	+	________	bye, boo, bow, bow, bough, boy, ball, burr
my	+	________	me, may, ma, moo, mow, my
whoa	+	________	we, wee, whee, way, whoa, wall
whee	+	________	

coronals

words

t T-T, Toto, tutu, today, teddy, teeny, tiny, Tony
d dada, dodo, ditty, daddy, Danny, Donny
n no-no, needy, nutty, naughty, nightie

phrases

do	+	____________	tea, T, tee, two, toe, tall
new	+	____________	day, do, dough, doll, dye
now	+	____________	knee, neigh, new, no, now
no	+	____________	

dorsals

words

k cookie, cougar
g goo-goo, gaga, gecko

phrases

go	+	____________	key, K, cow, car
			goo, go, guy

glottals

words

h hee-hee, ha-ha, hee-haw, ho-ho, hey-hey, hi-hi
ʔ uh-uh (no), uh-oh, uh-huh

Appendix E
Stimuli for Pattern 4: $C_{hom}VC_{hom}VC_{hom}$
Homorganic Consonants in a Closed Word Shape

Consonants are homorganic and the word shape is closed.

Like Pattern 3, stimuli in Pattern 4 are selected by constructing disyllabic words and phrases with homorganic consonants; however, in Pattern 4, stimuli have a closed word shape CVCVC.

labials

words

p peep-peep, pop-pop
b beep-beep, bebop
w whoop-whoop

phrases

bye	+	____________	peep, pop, poop, pup, pipe, Pam, palm
boy	+	____________	babe, Bob, beep, bop, beam, bam, bomb, boom, burp
me	+	____________	ma'am, mum, mom, mime, map, mop, mope, mob
my	+	____________	weep, whip, wipe, whim, wham, worm
we	+	____________	
whoa	+	____________	
______	+ up		pep, pop, pup, puma, palm, paper

coronals

words

t tattle, Tarzan, tennis, toilet, tonight, tunnel, turtle
d donate, (Mc)Donald, doughnut, downtown
n Nanette, needle, knotted, nineteen, noodle

phrases

do	+	___________	toot, tote, taught, tight, Ted, Todd, toad, tide, tin
new	+	___________	ten, tan, ton, tune, tone, town, turn
now	+	___________	deed, did, dead, dad, dude, Dan, den, dawn, dirt
no	+	___________	date, dot, done
tow	+	___________	Nan, none, noon, known, nine, noun, neat, knit, Nate, net
_____	+ too		gnat, nut, knot, newt, note, naught, night, need, Ned, nod
_____	+ did		gnawed, Nerd(s)

dorsals

words

k cooking, kicking, King Kong

g ganging (up)

phrases

go	+	___________	kick, cake, cook, coke, cork, Kirk, king
			gag, geek, gang, gong
_____	+ ick!		cake, cookie, coke

Appendix F
Stimuli for Pattern 5: $C_{het}VC_{het}V$ Heterorganic Consonants in an Open Word Shape

Consonants are heterorganic and the word shape is open.

Stimuli in Pattern 5 are selected by constructing disyllabic words and phrases that have a shape of CVCV and contain heterorganic consonants. Any consonant can be paired with any vowel. As with Patterns 3 and 4, continue to think broadly about consonant place of articulation, categorizing sounds by only four places of articulation: labial, coronal, dorsal, and glottal. The heterorganic consonant combinations include labial-coronal, labial-dorsal, labial-glottal, coronal-labial, coronal-dorsal, coronal-glottal, dorsal-labial, dorsal-coronal, dorsal-glottal, glottal-labial, glottal-coronal, and glottal-dorsal. Note that the production of word-medial /ʔ/ is dialectal and usage ranges from rare to frequent.

labial-coronal

words: potty, body, bunny, mighty, Minnie, muddy, money, messy, whiny, funny, fussy, fishy

phrases

me too!
bye _____: toe, tie, tea, knee, shoe
my _____: toe, tie, tea, knee, shoe
whoa _____: toe, tie, tea, knee, shoe
wow _____: toe, tie, tea, knee, shoe

labial-dorsal

words: picky, pokey, Mickey

phrases

me go, moo cow
bye _____: key, cow, goo, guy
my _____: key, cow, goo, guy
whoa _____: key, cow, goo, guy
wow _____: key, cow, goo, guy

coronal-labial

words: teepee, table, tummy, tv, diaper, dipper, Debbie, dauber, dummy, nippy

phrases
near me, no way, now me, dare me, do we?
no _____: bee, pea, bow, ma, moo

coronal-dorsal

words: tangy, tiki, turkey, knuck(le), nicke(l), doggie, yucky, ziggy-zaggy

phrases
you _____: go, 'kay?
no _____: go, key, cow
two _____: car(s), cow(s), key(s)

dorsal-labial

words: kiwi, cab(le), came(l), café, coffee, copy, cowboy, cubby, gimme, gobble, goopy, gummy (bear), guppy, keeper

phrases
ca(ll) me
go _____: pea, pa, bee, ba(ll), ma
go _____: pee, pay, purr, boo, bye, moo, mow, whee, whoa

dorsal-coronal

words: catt(le), Coty, caddie, canoe, Casey, cast(le), collie, cozy, giddy, goalie

phrases
go _____: tie, toe, tea, knee, shoe

glottal-labial

words: happy, hobby, hummer

phrases
hey _____: pa, bee, boy, doe, ma
hi _____: pa, bee, boy, ma

glottal-coronal

words: Heidi, honey, horsey, eenie, Uno

phrases

how do?

how to…?

how say…?

he ______: see(s), say(s), sigh(s), sew(s)

hi ______: T, tea, 2, D, day, doe, knee, Sue, sow

glottal-dorsal

words: hockey, hokey, huggy, hoagie

phrases

he go(es)

how go?

hey ______: key, K, koi, goo, guy

hi ______: key, K, koi, goo, guy

Appendix G
Stimuli for Pattern 6: $C_{vd}VC_{nas}$ Initial Voiced & Final Nasal Consonants

Initial consonants are voiced stops, nasals, glides, or fricatives. Final consonants are nasals.

Stimuli in Pattern 6 are selected by constructing monosyllabic words that begin with a voiced stop, nasal, glide, or fricative (/b, d, g, m, n, w, j, v, ð, z, ʒ/) and end with a nasal (/m, n, ŋ/).

stops

b_m beam, bam, bum, bomb, boom
b_n bean, bin, Ben, ban, bun, bone, burn
b_ŋ bing, bang, boing

d_m dim, dam, dum-dum, dome, dime
d_n Dean, den, Dan, done, dune, dawn, dine, down
d_ŋ ding-dong, dang, dung

g_m game, gum
g_n gain, ‘gain (again), gun, goon, gone, gown
g_ŋ gang, gong

nasals

m_m ma’am, mum, mom, mime
m_n mean, mane, men, man, moon, moan, mine
m_ŋ mung

n_m name, numb, gnome
n_n none, noon, known, nine, noun
n_ŋ

glides

w_m	whim, wham, worm
w_n	wean, win, wane, when, won, one, whine
w_ŋ	wing
j_m	yam, yum
j_n	yawn, yearn
j_ŋ	young

fricatives

v_m	voom
v_n	vane, van, vine
v_ŋ	
z_m	zoom
z_n	
z_ŋ	zing

Appendix H
Pattern 7: $C_{vd}VC_{vl}$
Initial Voiced & Final Voiceless Consonants

Initial consonants are voiced stops, nasals, glides, or fricatives. Final consonants are voiceless stops or fricatives.

Stimuli in Pattern 7 are selected by constructing monosyllabic words that begin with a voiced stop, nasal, glide, or fricative (/b, d, g, m, n, w, j, v, ð, z, ʒ/) and end with a voiceless stop or fricative (/p, t, k, f, θ, s, ʃ/).

stops

b___p beep, bop, boop, burp
b___t beet, beat, but, bet, bat, boot, boat, bought, bite, ‘bout (about), Burt
b___k beak, bake, back, buck, book, bike
b___f beef, buff
b___s base, bass, bus, boss

d___p deep, dip, dope
d___t date, dot, dote, doubt, dirt
d___k Dick, deck, duck, dock, duke, dike
d___f deaf
d___s dis, dice

g___p gap, goop
g___t gate, get, got, goat
g___k geek, (gecko)
g___f goof, golf
g___s geese, guess, Gus, goose

nasals

m___p map, mop, mope
m___t meat, mitt, mate, met, mat, mutt, moat, might
m___k meek, Mick, make, Mack, muck, mike
m___f muff
m___s miss, mess, mass, moose, moss

n___p nip, nap, nope
n___t neat, knit, Nate, gnat, nut, not, newt, note, naught, night
n___k nick, neck, knick-knack, knock, Nuk
n___f ‘nuff (enough), knife, Nerf
n___s niece, noose, nice

glides

w___p weep, whip, whoop
w___t wheat, wait, wet, what, white
w___k weak, wick, wake, whack, wok, woke, walk
w___f whiff, wife
w___s Wes, worse

j___p yap, yup
j___t yet, yacht
j___k yack, yuck, yike
j___f
j___s yes, use

fricatives

v___p
v___t vet, vat, vote, vault
v___k
v___f
v___s vase, vice

z___p zip, zap
z___t
z___k Zach
z___f
z___s

Appendix I
Pattern 8: CV + CV(C) Fixed Syllable

green = least phonetically complex
orange = more phonetically complex
black = personal names

PEE / P
puppy
teepee
nippy
weepy
happy
guppy
soapy

PULL
people
maple
steeple
ripple

BEE / B
pb
baby
ha-ha
maybe
hobby
lobby
ruby
Scooby (Doo)
Bobby

BULL
pebble
bubble
bumble
table
tumble
double
wobble
cable
gobble
fable
label
fumble
thimble

TEA / T
potty
mighty
nightie
nutty
kitty
footie

DEE / D
buddy
body
teddy
tidy
daddy
kiddy
muddy
Woody
hoodie
goodie
lady
shady
ready

KEY
pokey
cookie
turkey
monkey
hockey
Mickey (Mouse)
hokey pokey
jockey
leaky
lucky
rocky

KING
peeking
picking
packing
poking
baking
biking
ticking
taking
kicking
cooking
quacking
making
knocking
waking
seeking
sacking
shaking
choking
joking
leaking
licking
locking
liking
raking
rocking

ME
tummy
mommy
yummy
gimme
gummy
foamy
Amy
Timmy
Tommy
Jimmy
Jamie

KNEE
penny
pony
bunny
bony
teeny
tiny
money
Winnie (the Pooh)
honey
funny
sunny
shiny
rainy

WAY

away
one-way
highway
hallway
seaway
raceway

SEE / SEA

icy
posse
messy
fussy
lacy

SING

icing
pacing
tossing
kissing
hissing
guessing
facing
fussing
chasing
lacing
racing

Z

easy
pansy
busy
dizzy
daisy
noisy
hazy
cozy
fuzzy
lazy
rosy

LEE

alley
belly
bully
tally
deli
dolly
hilly
holly
holey/
holy
collie
goalie
filly
valley
silly
chili/
chilly
jelly
jolly
lolli(pop)
really
rally
Allie
Billy

LOW

aloe
pillow
polo
mellow
willow
yellow
halo
hello
hollow
fellow
silo
shallow
jello

Appendix J
Target - Index of Phonetic Complexity (T-IPC) Data Form

Identifying Information

Participant:________________________________

Age:________________________________

Sex:________________________________

Date:________________________________

Examiner:________________________________

Notes:________________________________

____

____

Results

Total # Targets:________________________________

T-IPC Value Range:________________________________

Mean T-IPC Value:________________________________

Standard Deviation:________________________________

Notes:________________________________

____

____

Targets Phonetically Transcribed	Indices								Total T-IPC Values
	1 D	2 FAL	3 R	4 FC	5 3+	6 SPV	7 CC	8 CCV	

Appendix K
Production - Index of Phonetic Complexity (P-IPC) Data Form

Identifying Information

Participant:____

Age:____

Sex:____

Date:____

Examiner:____

Notes:____

Results

Total # Productions:____

P-IPC Value Range:____

Mean P-IPC Value:____

Standard Deviation:____

Notes:____

Productions Phonetically Transcribed	Indices								Total P-IPC Values
	1 D	2 FAL	3 R	4 FC	5 3+	6 SPV	7 CC	8 CCV	

References

Amayreh, M. M., & Dyson, A. T. (2000). Phonetic inventories of young Arabic-speaking children. *Clinical Linguistics and Phonetics*, 14, 193-215.

Davis, B., & MacNeilage, P. (1995). The articulatory basis of babbling. *Journal of Speech and Hearing Research,* 38, 1199-1211.

Davis, B., & Velleman, S. L. (2000). Differential diagnosis and treatment of developmental apraxia of speech in infants and toddlers. *Infant-toddler Intervention*, 10, 177-192.

Dale, P. S., & Hayden, D. A. (2013). Treating speech subsystems in childhood apraxia of speech with tactual input: The PROMPT approach. *American Journal of Speech- Language Pathology,* 22, 644-661. https://doi.org/10.1044/1058-0360(2013/12-0055)

Eldridge, K. A. (2006). Phonological complexity and speech disfluency in young children (Doctoral dissertation). Retrieved from UMI Press. (3255714)

Gayraud, F., Barkat-Defradas, M., Lahrouchi, M., & Ben Hamed, M. (20xx). Development of phonetic complexity in Arabic, Berber, English, and French. *Canadian Journal of Linguistics*, 63, 527-555. http://dx.doi.org/10.1017/cnj.2018.9

Howell, P., & Au-Yeung, J. (2007). Phonetic difficulty and stuttering in Spanish. *Clinical Linguistics and Phonetics*, 21, 111-127. https://dx.doi.org/10.1080%2F02699200600709511

Howell, P., Au-Yeung, J., Yaruss, J. S., & Eldridge, K. (2006). Phonetic difficulty and stuttering in English. *Clinical Linguistics and Phonetics*, 20, 703-716. http://dx.doi.org/10.1080/02699200500390990

Jakielski, K. J. (1998). *Motor organization in the acquisition of consonant clusters* (Doctoral dissertation). Retrieved from UMI Press. (9838002)

Jakielski, K. J. (1998, April). *Early acquisition of consonant clusters: A phonetic perspective.* Paper presented at the Annual Child Phonology Conference, Charlottesville, VA.

Jakielski, K. J. (2000, June). *Quantifying phonetic complexity in words: An experimental index.* Paper presented at the annual Child Phonology Conference, Cedar Falls, IA.

Jakielski, K. J. (2002, May). *The Index of Phonetic Complexity: Preliminary findings*. Paper presented at the Annual Child Phonology Conference, Wichita, KS.

Jakielski, K. J., & Doyle, E. (2006, April). *Acquisition of phonetic complexity in two-year-old children*. Presentation at the Annual Convention of the Missouri Speech-Language-Hearing Association, Lake of the Ozarks.

Jakielski, K. J., & Egan, T. L. (1999, November). *Motor constraints affecting speech output in developmental apraxia of speech*. Poster session presented at the Annual Meeting of the American Speech-Language-Hearing Association, San Francisco, CA.

Jakielski, K. J., English, S. M., & Miller, K. J. (2000, January). *Phonetic effects on lexical selectivity: Current research.* Seminar presented at the Winter Meeting of the Quad Cities Speech-Language-Hearing Association, Moline, IL.

Jakielski, K. J., & Matyasse, R. (2005, April). *Analyzing the acquisition of phonetic complexity in one-year-old children.* Presentation at the Annual Convention of the Missouri Speech-Language-Hearing Association, Lake of the Ozarks.

Jakielski, K. J., Matyasse, R. L., & Doyle, E. N. (2006, November). *Acquisition of phonetic complexity in children 12-36 months of age.* Poster presented at the Annual Convention of the American Speech-Language-Hearing Association, Miami, FL.

Jakielski, K. J., Ward, P., & Duncan, V. (2002, November). *A new method for measuring articulatory complexity.* Poster presented at the Annual Convention of the American Speech-Language-Hearing Association, Atlanta, GA.

Lee, H., Gambette, P., & Barkat-Defradas, M. (2014). iPhocomp: Calcul automatique de l'indice de complexité phonétique de Jakielski. *Journées d'Etudes sur la Parole*, XXXè, 622-630. https://hal-upec-upem.archives-ouvertes.fr/hal-01277047/document

Leonard, L. B., Schwartz, R. G., Morris, B., & Chapman, K. (1981). Factors influencing early lexical acquisition: Lexical orientation and phonological composition. *Child Development*, 52, 882–887.

Maas, E., Gildersleeve-Neumann, C. E., Jakielski, K. J., & Stoeckel, R. (2014). Motor-based intervention protocols in treatment of childhood apraxia of speech (CAS). *Current Developmental Disorders Reports*, 1, 197-206.

Maas, E., Robin, D. A., Austermann Hula, S. N., Freedman, S. E., Wulf, G., Ballard, K. J., & Schmidt, R. A. (2008). Principles of motor learning in treatment of motor speech disorders. *American Journal of Speech-Language Pathology*, 17, 277-298.

MacNeilage, P. F., & Davis, B. L. (1990). Acquisition of speech production: Frames, then content. In M. Jeannerod (Ed.), *Attention and performance XIII: Motor representation and control* (pp. 453-475). Hillsdale: Laurence Erlbaum.

Morris, S. R. (2009). Test-retest reliability of independent measures of phonology in the assessment of toddlers' speech. *Language, Speech, and Hearing Services in Schools*, 40, 46-52.

Paul, M., & De Serres, S. (2018, May). *Can an articulatory complexity index be used to predict children's performance?* Paper presented at the SAC-OAC Conference, Edmonton, Canada.

Preston, J. L., Maas, E., Whittle, J., Leece, M. C., & McCabe, P. (2016). Limited acquisition and generalization of rhotics with ultrasound visual feedback in childhood apraxia. *Clinical Linguistics & Phonetics*, 30, 363-381. https://doi.org/10.3109/02699206.2015.1052563

Ranta, K. A., & Jakielski, K. J. (1999, November). *Phonetic effects on lexical selectivity: A pilot study.* Poster session presented at the Annual Convention of the American Speech-Language-Hearing Association, San Francisco, CA.

Schmidt, R. A., & Lee, T. D. (2011). *Motor control and learning: A behavioral emphasis* (5th ed.). Champaign, IL: Human Kinetics.

Schmidt, R. A., & Wrisberg, C. A. (2007). *Motor learning and performance: A situation-based learning approach* (4th ed.). Champaign, IL: Human Kinetics.

Schwartz, R. G., & Leonard, L. B. (1982). Do children pick and choose? An examination of phonological selection and avoidance in early lexical acquisition. *Journal of Child Language*, 9, 319–336.

Schwarz, R. G., Leonard, L. B., Loeb, D. M., & Swanson, L. A. (1987). Attempted sounds are sometimes not: An expanded view of phonological selection and avoidance. *Journal of Child Language*, 14, 46-51.

Shriberg, L. D., Austin, D., Lewis, B. A., McSweeny, J. L., & Wilson, D. L. (1997). The Speech Disorders Classification System (SDCS): Extensions and lifespan reference data. *Journal of Speech, Language, and Hearing Research*, 40, 723-740.

Stoel-Gammon, C. (1987). Phonological skills of 2 year olds. L*anguage, Speech, and Hearing Services in Schools*, 18, 323-329.

Stoel-Gammon, C., & Cooper, J. (1984). Patterns of early lexical and phonological development. *Journal of Child Language*, 11, 247-271.

Strand, E. A. (2020). Dynamic Temporal and Tactile Cueing: A treatment strategy for childhood apraxia of speech. *American Journal of Speech-Language Pathology*, 29, 30-48. https://doi.org/10.1044/2019_AJSLP-19-0005

Weiss, A.L., & Jakielski, K. J. (2001, June). *Phonetic complexity measurement and prediction of children's disfluencies: A preliminary study.* Proceedings from the 4th International Speech Motor Conference, (pp. 278-281). Nijmegen, the Netherlands.

Weiss, A. L., & Jakielski, K. J. (2003, July). *Phonetic complexity and disfluencies: A closer look.* Poster presented at the Annual Child Phonology Conference, Vancouver, B.C., Canada.

Yorkston, K. M., Beukelman, D. R., Strand, E. A., & Hakel, M. (2010). *Management of motor speech disorders in children and adults* (3rd ed.). Austin, TX: Pro-Ed.

Online freeware program to calculate IPC scores at
https://igm.univ-mlv.fr/~gambette/iPhocomp/EN/index.php

Kathy J. Jakielski, Ph.D., CCC-SLP, ASHA Fellow

Professor of Communication Sciences & Disorders
Florence C. and Dr. John E. Wertz Chair in Liberal Arts and Sciences
Augustana College
Rock Island, Illinois