The Perfect Oral Motor Storm

Supportive Evidence for the Use of Oral Sensory-Motor Methods to Remediate Speech Sound Productions

(#5)

The New Wave:

Capability-Based Speech Sound Therapy

Char Boshart, M.A., CCC-SLP
SpeechDynamics.com
Char@SpeechDynamics.com

"In their recent 2018 article, Luo, et al., asks the question if lateral bracing is truly necessary for speech. They conclude that "lateral bracing is actively maintained under different degrees of jaw perturbation, suggesting that bracing is a *crucial component of speech production.*" Therefore, it is a critical piece to include in therapy. Interestingly, MeLeod (2011; took place in Australia) surveyed SLPs and found that "SLPs did not fully understand the role of the lateral regions of the tongue during the articulation of speech sounds." *We're addressing that issue!*
-- Char Boshart, M.A., CCC-SLP

Welcome! Glad you're here!

You're holding in your hand a document that is one part of a series. The following details how the documents and the podcasts are grouped.

The Perfect Oral Motor Storm is organized in ***Five Waves,*** **i.e. information that details the progressive events that occurred and accumulated over the past two decades into the tsunami known as the oral motor controversy.**

The information is available in two formats:

- **Printed Documents (Welcome + Five Waves + The New Wave),** and
- **Five Podcasts that were presented on *The Speech Link***

The Perfect Oral Motor Storm series is sequenced and grouped in the following manner:

#1: Document and Podcast
Welcome to the Storm! Goals, The Controversy, and The Assumptions

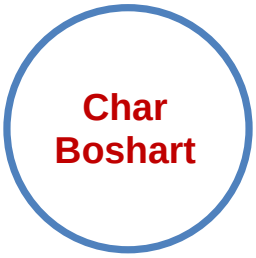
#2: Document and Podcast
The First Wave: Evidence Based Practice
The Second Wave: Dr. Lof's Survey
The Third Wave: Dr. Forrest's Study

#3: Document and Podcast
The Fourth Wave: Extensive Research Data

#4: Document and Podcast
The Fifth Wave: Dr. Lof's Five "Theoretical Reasons to Question Using NSOME"

- Reason #1: Part-Whole Training and Transfer
- Reason #2: Strengthening the Articulatory Structures
- Reason #3: Relevancy of NSOME to Speech
- Reason #4: Task Specificity
- Reason #5: Warm-Up, Awareness, Metamouth

#5: Document and Podcast
The New Wave: A Case for Capability-Based Therapy



Although I typically don't share all of this I want you to know where I'm coming from. Following are personal details about my background and experience.

In the 1970s, one of my favorite under-grad professors gave us each a small book he had written on the oral resting posture. It made sense, I was intrigued, and he inspired me to move forward on a path of oral investigation for the next 40+ years.

Over the course of those years,

- I received my Master's in Speech-Language Pathology from Western Michigan University where I was honored to have Dr. Charles Van Riper as my professor.

- I returned to my alma mater, Loma Linda University, and taught articulation and language courses full-time, for several years; I was the department chair for two years. Also, during that time, in the evening I saw clients of all ages and disorders. I loved being able to share first-hand therapy knowledge with my college students.

- Although I loved teaching, I realized therapy was my calling. After leaving the university life, I worked in the schools and did private practice at night. I became interested in the oral stage of swallowing, commonly known as "tongue thrust." I had the distinct pleasure of studying one-on-one with Dr. Marv Hanson in his office in Utah and became a certified orofacial myologist through the IAOM.

I learned that researching and studying about therapy was also my calling, and very exciting. I became extremely interested in the oral physiological workings—including the hard tissue, soft tissue, and respiration—of speaking, swallowing, and chewing. Since the oral mechanism is a crossroads of disciplines, I branched out from speech pathology. I studied and picked the brains of those at the Loma Linda School of Dentistry in pediatrics, orthodontics, and maxillo-facial, became a frequent visitor over a two-year period and learned all about muscles with Dr. Raymond Hall at Loma Linda University School of Physiology and Pharmacology, I attended occupational therapist seminars where I was the only SLP, and spent many hours duplicating journal articles at the Del Webb Library, and reading and studying them.

Then I met Pam Marshalla at an ASHA Convention. We hit it off, compared notes, and amazingly we were on a similar "oral motor" track. She asked me to do seminars with her Innovative Concepts company. She, also, asked me to write a "handbook" of my course content to share with the attendees. I didn't have one of those and I had never written anything. But I had acquired numerous resources and a ton of knowledge. It took me well over a year to pull it all together.

That was 1993. I spoke for Pam's company, then started my own company, Speech Dynamics, Inc., in 1995. Since that time, my best estimate is that I've given over 1300 one- and two-day seminars and presentations at conventions. It's been my distinct privilege to meet and talk with thousands of dedicated, intelligent, competent speech-language pathologists who do incredible therapy. I have such admiration for the men and women in our field.

Little did I know that this introverted person that I am, would one day travel, meet so many great people, schlep through airports, do seminars and videos, and write books, articles, blogs, and host podcasts.

The therapy that I'm passionate about, applied with hundreds of children and adults, and have studied for so long is under attack. It's my pleasure to not only defend it but explain and support why oral motor therapy is not only effective but is the *heart of speech therapy.*

Outline

Within *The Perfect Oral Motor Storm* documents, previous "Waves" have been critiques and explanations. This "Wave" is different. This one is called The NEW Wave and I propose an oral-sensory motor approach to apply with speech sound delays and disorders. It is called, *Capability-Based Speech Sound Therapy.* The following is organized in five sections and details the theoretical rationale. No doubt, you may already apply some of these principles and techniques in your therapy.

Speech: The Goal

Speech Descriptors
Stabilization: The Essential Movement Component

Speech Sound Grouping

Grouping of Speech Sound Productions Physiologically

Speech Sound Production Elements

1. External Lingual Stabilization
2. Internal Lingual Stabilization
3. Speech Sounds Are "Vertical"
4. Speech Movements are Refined, Precise and Differentiated
5. Intra-Oral Sensory Interaction During Speaking

The Oral Resting Posture: The Harmonizer

The Positions
The Rationale and Importance

Capability-Based Speech Production Therapy
Seven Principles

1. Address Speech **Production Elements** (generate oral capability)
2. Apply **Developmental Differentiation** speech acquisition principles
3. Approach therapy as a **Capability-Building Process** that occurs over time
4. Include **Speech Sound Relevancy** throughout
5. Apply **Sensory Assists** throughout; as needed and tolerated
6. Determine and Compensate for **Production Obstacles**
7. Utilize **Practice Principles**

The New Wave

Capability-Based Speech Sound Therapy

Char Boshart, M.A., CCC-SLP

Currently, there are contentious debates and little evidence to support what we SLPs do in speech and language therapy. *The topic of *oral motor* is but one area under question, albeit, it is the most openly controversial.

In the section on "Research Data" (the Fourth Wave) we discussed the extensive, and perhaps the highest quality Evidence-Based Systematic Review (EBSR) on oral motor (McCauley, et al., 2009). You may recall their comprehensive criteria for including or excluding articles and their far-reaching databases that covered the years between 1960 to 2007.

One of their primary findings was the extent and diversity of ages and disorders of participants within the final 15 EBSR studies. For example, the participants ranged from infants to elderly adults and exhibited a wide variety of medical diagnoses and communication disorders: mild articulation disorder, Down syndrome, cerebral palsy, stoke, and cleft palate. In addition, the types of oral motor exercises and interventions used were equally diverse: oral stimulating plates, myofunctional therapy, range of motion exercises, strengthening exercises, sensory stimulation, and blowing/sucking tasks.

McCauley and colleague's findings underscore the wide range of how oral motor can be interpreted and applied. As previously stated in an earlier section, "oral sensory-motor techniques can be applied to anyone that has a mouth."

▪ ▪ ▪

We can all agree that no matter the type of therapy each of us implements it must be grounded in a solid theoretical foundation.

I offer an evidence-based theoretical rationale for physiologically based therapy. It is called *Capability-Based Speech Sound Therapy.* The methodology centers around the tangible components of speech production that can be adapted and applied accordingly to the age and characteristics of each *client's capabilities.* As reflected in the findings by McCauley, et al. (2009), this form of therapy is also client-based as are many types of oral sensory motor approaches. SLPs meet clients where they are on their developmental path and guide them toward speech production based on their needs and abilities.

Although this specific methodology is primarily for children who are verbal, but lack speech clarity (to one degree or another), the rationale can be applied to low-verbal or non-verbal children, and even adults. As we'll find out, the points of speech stabilization and mobilization apply to all.

I've researched the topic of physiologically based speech therapy for several decades and have found the mouth to be a crossroads of disciplines. Therefore, the following referenced information is from a variety of specialties including speech pathology, dentistry, orthodontics, maxilla-facial surgery, physiology, neurology, occupational therapy, physical therapy, respiratory, and even psychology.

My investigations and conclusions are presented from a *practical speech-language therapist's and therapy perspective*. At least 80% of the principles are based in research evidence. The remaining is based on my study, interpretations, experience, and observations.

*Credible research reviews have determined that Language Therapy and Service Delivery also lack research evidence. Please refer to "Extensive Research Data" printed in the Fourth Wave, and #3 of the Documents and *The Speech Link* podcast.

Speech: The Goal

In capability-based therapy—no matter the client's age, type or extent of speech production obstacles that the person displays—the ultimate goal is always *speech production.* In therapy, the component commonalities across speech production (discussed below) are addressed and modified according to the individual's age and capabilities.

Critical to this viewpoint is one's interpretation of Speech (with a capital S). It is imperative to have a core paradigm, or at least a definition or description of Speech.

Dr. Kent (2015) states that "…speech is rarely defined at all. In its various documents, ASHA apparently does not define speech, but does define a speech disorder as an impairment of the articulation of speech sounds, fluency, and/or voice (ASHA, 1993).

So, what is your Speech paradigm and does it really matter if you have one? I think so. As SLPs, our belief about Speech—the ultimate functional goal—influences and shapes *how we do therapy.*

Do you believe that Speech has phonetic qualities and is a system of oral interactive movements? Maas (2014) offers his definition: "Speech production is a complex motor skill that requires coordination across many different muscle groups with extraordinary spatiotemporal demands."

Or, to you, is Speech a phonological language system and a cognitive-auditory function? Ziegler and Ackermann (2013) explain motor events in speech "as a specific branch of linguistics, i.e. the *sound* systems of language."

Regarding therapy and the current controversy, it is understandable why some in the phonology-camp don't comprehend how Speech can be parsed then combined. After all, how does one parse a speech sound that is perceived as an *auditory* result? Could this be one reason for the controversy? Most of us do use the term "speech *sound* disorder." This emphasizes the resultant speech *sound*, not the speech movement *act*.

As a therapist that appreciates a visible and tangible oral mechanism to work with, I lean toward the phonetic camp. But perhaps, like me, you believe Speech is a combination of both. Dr. Kent (2015) defines speech as "movement or movement plans that produce as their end result acoustic patterns that accord with the phonetic structure of a language."

With that said, perhaps definitions have always been contentious. I found an interesting article in a past ASHA journal:

Report of Subcommittee on Articulation Problems; Research Needs
"The committee did not feel that adequate definitions were available, and therefore recognized:
a. The need to develop a more satisfactory definition of 'articulation.'
b. The need to develop a more satisfactory definition of 'articulation disorder.'"
J. Villarreal, R. Schiefelbusch, W. Pronovost, R. Milison
Journal of Speech and Hearing Disorders, Monography Supplement 5,
September 1959, page 14.

Speech, speech disorder, and articulation definitions are numerous. However, apparently finalized, agreed-upon definitions are still a work in progress. I suggest we each study the principles and choose for ourselves.

Speech Descriptors

As a therapist, I have appreciated the speech descriptors that several authors in our field have generated through the years. They've put forth speech classifications and categories that describe "correct" and "incorrect" speech characteristics. Following, in my view, are the most prevalent and well-known:

- **Articulatory Descriptors; Place, Manner, Voice**: For example, /p/ is considered a bilabial, stop, and voiceless, and /s/ is an alveolar, fricative, and voiceless, (Ladefoged and Maddleson, 1996). This form of speech categorization/description continues to be used by therapists and professors. The terminology is direct, accurate and helpful in analyzing and grouping speech sounds. Unfortunately, it is not exceedingly helpful in *doing* therapy.

- **Binary Distinctive Features:** For example, /p/ is -vocalic, +consonantal, -sonorant, -coronal, +anterior, -high, -low, -back, -rounded, -distributed, -nasal, -lateral, -continuant, +tense, -voiced, -strident. (Jakobson, Font, Halle, 1963.)

  Distinctive features of phonemes appear to have fallen from favor, at least with therapists. Even as early as 1976, Parker expressed, "Chomky's and Halle's distinctive features cannot be applied fruitfully to all instances of misarticulation…. The crucial point is that no one-to-one relationship necessarily exists between distinctive features and production features." In my opinion, distinctive features are too data-intensive to apply in the real world.

- **Phonological Processes:** These are "patterns of oral errors" (substitutions and omissions) that typically developing children use when developing speech; they do not describe correct speech sound productions. The terms and concepts are used by today's therapists, professors, and researchers.

  - Substitution: backing, fronting, gliding, stopping, vowelization, affrication, deaffrication, alveolarization, depalatalization, labialization.
  - Assimilation: assimilation, denasalization, final consonant devoicing, prevocalic voicing, coalescence, reduplication.
  - Syllable Structure: cluster reduction, final consonant deletion, initial consonant deletion, weak syllable deletion, epenthesis.

The phonological view came into prominence in the 1970s and '80s and added the linguistic and auditory components. Although one could say there are two distinct camps in our field, the reality is that "speech is not only governed by motor processes but also by phonological and phonetic principles," (Kent, 2015). Thirty years ago (1990) Janet Pierrehumbert suggested, "Both phonology and phonetics are necessary to understand language as a means of communication between people."

Stabilization: The Essential Movement Component

Stabilization and mobilization are frequently discussed in whole-body control and exercise books and articles (Brooks, 1983). This principle is the basis of control of large and small body parts during functions and non-functions. "[The] stabilization process consists of establishing active muscular constraints to minimize the degrees of [movement] freedom…." (Borghus, et al., 2008). Therefore, stabilization is needed to generate refined movement.

Stabilization enables controlled movement via levels of (*internal*) muscle contractions, as in downhill skiing, and (*external*) tactile interaction, as in placing the edge of your hand on the table to stabilize as your fingers mobilize.

Controlled movement requires nearby stability to one degree or another. It is doubly so within the confines of the limited oral environment. Given the number and type of refined movement requirements for speech production, lingual stabilization—appropriate *external* and *internal stabilization*—is absolutely imperative. Many of our speech-kids lack appropriate lingual stabilization to generate appropriate lingual mobilization for speech production, (Fletcher, 1992; Stone and Lundberg, 1996).

Speech Sound Grouping
(To Apply in Analysis and Therapy)

There is sparse information on lingual physiological characteristics of speech sound productions. Following are three excellent articles that suggest there are a limited number of tongue shapes that occurs during speech production.

- Stone and Lundberg's1996 electropalatography (EPG) study on tongue movements during speech sound production categorized *tongue shapes into four classes:* front raising, complete groove, back raising, and two-point displacement.

- Green and Wang (2003) identified *four lingual patterns, also by tongue shapes*: Blade elevation with dorsum depression (alveolars, palatoalveolars, the retroflex); body elevation (/j/); dorsum elevation (velars and swallowing), and anterior-blade elevation with body depression (/l/), and

- Stolar and Gick (2013) submit four *tongue surface shapes that occur during speech production.* They call them the Lingual Curvature Index.

Grouping of Speech Sound Productions Physiologically
(A Suggestion)

The three above studies recognize similar lingual grooving and lingual (front, back, and mid) elevations. My suggestion for grouping lingual characteristics for speech sound productions is, in part, inspired by the three studies plus the exceptional work produced through the years by Fletcher, and by Gibbons. There are underlying similarities in points of stabilization and mobilization, although they did not always use those terms.

Keep in mind that all speech sound productions contain specific lingual- and labial-parts that stabilize and parts that mobilize. The corners of the lips stabilize (contract) to provide anchorage for the mid-area of the lips to move in a refined, differentiated manner for /p/, /b/, /m/ /w/ and "wh". Regarding the jaw, a mature jaw does not anchor in place; the jaw muscles minimally co-contract to vertically adjust according to the needs of the lips and tongue.

According to Gibbon (1999), "The two articulators are the tongue tip/blade and the tongue body. The tongue body can be further divided into front and back regions…." Following is a straight-forward and therapeutically helpful way to group English lingual consonant speech sounds; only lingual stabilization and mobilization are addressed.

Similar to the three studies that identified lingual contours, the following lingual speech sound grouping is based on *lingual planes of movement during speech production.*

- Front-tongue Vertical Sounds: /t/, /d/, /n/, /s/, /z/, /ʃ/, /ʒ/, /tʃ/, /dʒ/, /l/, and the retroflex /r/
  The tongue braces *externally* within the upper dental arch and achieves lateral dental/palatal stabilization; it stabilizes *internally* via mid-tongue contraction (the groove/tongue bowl).

- Back-tongue Vertical Sounds: /k/, /g/, /ng/, and the back-up /r/
  The "back-tongue corners" brace on the retromolar pads (a dentistry term) behind the top, back teeth while the mid-tongue (of the elevated back-tongue) moves vertically.

- Mid-tongue Vertical Sound: /j/
  The mid-tongue raises and lowers, while the tongue-sides bilaterally brace on the side teeth.

- Whole Tongue Horizontal Sounds: /θ/ and /ð/
  These two sounds require internal whole-tongue tension while moving horizontally. The lateral margins may contact and slide along the cutting surfaces of the top, side teeth. (This may be more of a guide than points of stabilization.)

Most speech sounds require "vertical" tongue movement; only two speech sounds require "horizontal" tongue movement. Unsure about that? Notice your own tongue's plane of movement as you move from your tongue's resting position into the speech sound placement. Also, note that stabilization has two forms: *external* and *internal;* we'll discuss both of those below.

Many of our speech-kids move their tongue horizontally for front-tongue (and/or back-tongue) vertical speech sounds. It's easy to visually determine why they have difficulty producing correct speech production movements: Their tongue lacks appropriate stabilization to facilitate appropriate vertical mobilization.

In therapy, when consistent horizontal tongue movement is present (for speech productions that are supposed to be vertical), you may hear a sound that *sounds* similar to the target but may not be appropriately stabilized and mobilized; think inter-dental, horizontal productions. Do know that generalization and transfer may be difficult without appropriate external and internal lingual stabilization—for all speech sounds.

Speech Sound Production Elements

It has been said that speech sound productions cannot be parsed (Lof, 2017; Forrest, et al., 2008, plus others), i.e., meaning speech cannot be segmented into components that directly relate to speech sound productions. If one believes that the mechanics of speech is just about mouth-parts, or speech subsystems, or speech sound descriptors (e.g. plosive, fricative, etc.), that claim is certainly accurate.

The following, however, provides simple speech sound components. They are comprised of the common movements across speech sound productions that can be addressed therapeutically. As a therapist, this knowledge gives me the ability to efficiently analyze and improve my client's oral capabilities as they directly relate to the speech components of the speech sound. With that said, it is critically important, to then layer and combine the elements into the target speech sound production. Generalization and transfer into connected speech is optimized due to effectively addressing the speech components.

Following are the speech sound production physiological elements. Speech:

1. Requires *External* Lingual Stabilization
2. Requires *Internal* Lingual Stabilization
3. Is primarily comprised of *Vertical* Lingual Movements
4. Movements are Refined, Precise and Differentiated
5. Involves Intra-Oral Sensory Interactions

1. External Lingual Stabilization

(Fletcher, 1992; Stone, et al., 1992; Gick, Wilson & Derrick, 2013; Gibbon and Wood, 2010, plus others)

External lingual stabilization, commonly referred to as "bracing" provides anchorage for controlled mobilization (Gick, 2013; Lee, Gibbon, Oebels, 2015; Gick et al, 2017). Degrees of contact vary on the maxillary side teeth, perimeter of the palate, and the retromolar pads. Lee, et al. (2015; in Ireland), provide reasons for lateral margin bracing:

- It forms a seal with the palate and upper teeth
- It directs the airflow centrally
- It helps anchor and stabilize the tongue [for controlled movement]
- It aids in the formation of tongue shapes for articulation
- It enables the build-up of air pressure during alveolar consonant production and,
- It provides somatosensory feedback regarding its position…." (In my opinion, this is one of the most important reasons.)

Until Gick's 2017 study, apparently the term lingua-dental "bracing" referred to *light contact* of the sides of the tongue against the side teeth, instead of energetic mechanical support. This statement validates the fact that the tongue externally anchors itself to facilitate controlled, refined movements.

In addition, Gick (2017) concluded, "…tongue bracing is both pervasive and active in running speech and essential in understanding tongue movement control," (p. 494).

Therefore, not only is it important for the tongue to be lingua-dentally braced during individual speech sounds, but also *during connected speech.* "The tongue is almost always constantly braced against the lateral surfaces during running speech," (Gick and Allen, 2013). Lateral bracing helps the tongue to "keep its place" during connected speech and to move smoothly from speech-contact to speech contact.

In their recent 2018 article, Luo, et al., asks the question if lateral bracing is truly necessary for speech. They conclude that "lateral bracing is actively maintained under different degrees of jaw perturbation, suggesting that bracing is a *crucial component of speech production.*" Therefore, it is a critical piece to include in speech therapy. Interestingly, MeLeod (2011; took place in Australia) surveyed SLPs and found that SLPs did not fully understand the role of the lateral regions of the tongue during the articulation of speech sounds.

But the information is getting out there. For more on this topic see my Therapy Matters blog. Go to SpeechDynamics.com/blog; Blog #7 "Speaking Tongues are Activity Braced."

2. Internal Lingual Stabilization

(Kier and Smith, 1985; Smith and Kier, 1989; Stone and Lundberg, 1996; Green and Wang, 2003; Kent, 2004; Stolar and Gick, 2013, and others)

In E.W. Scripture's 1912 book *Stuttering and Lisping* it contained phoneme-by-phoneme lip and tongue facilitation techniques. *It also included techniques to elicit a midline groove for /s/.*

In 1985, the lingual groove/tongue bowl was formally identified and discussed in the physiology world in Kier and Smith's biology article "Tongues, Tentacles and Trunks: The Biomechanics of Movement in Muscular-Hydrostats." Think of an elephant's truck, an octopus' arms, and the human tongue.

Smith and Kier (1989) explain that muscular hydrostats are "notable for their functional diversity and complexity of movement, they are distinctive because they are composed almost entirely of muscle; they lack any obvious system of skeletal support." There are no bony-joints to move or provide control. "*The musculature itself both creates movement and provides [internal] skeletal support for that movement."*

Internal lingual stabilization is manifested either via *whole tongue* internal contraction (for "th," the back-up /r/, and perhaps "sh"), and/or *mid-tongue gradients* of contraction (identified as a groove or tongue bowl in most front-tongue vertical speech sounds). Mid-tongue contraction stabilizes and enables the front tongue to elevate and curl to generate a variety of front-tongue vertical speech sounds (based on Kent, 2004; Green and Wang, 2003).

The spatiotemporal relationships between the tongue and the alveolar ridge, the hard palate, the velum, and even the front teeth are expedited by stabilization. Where would the tongue be without it? Many of our speech-children supply good examples. If they do not apply appropriate lingual stabilization (or are unable to access it) typically they contract other body parts apparently in an innate effort to "stabilize." For example, either they bite their teeth together, contract their lips, inappropriately contract the whole tongue, compress their lips against their teeth, tighten their facial muscles, or tighten their throat muscles, etc.

Green and Wang (2003) suggest that, "An improved understanding of the extent of functional regionality within the tongue will be important for explaining features of normal and disordered speech and swallowing." Yes, it most definitely would.

3. Speech Sounds are "Vertical"

(Kent, 2004; Liu, et al., 2018)

"Appropriate lingual stabilization enables mobilization for vertical, refined, precise, agile movements," (Liu, et al., 2018). In addition, Kent (2004) explains that the "bending of the tongue is achieved through differential contraction of the intrinsic muscles [of the lingual muscular hydrostat], operating under the constraint of conservation of volume."

As previously mentioned, most lingual speech sounds are "vertical." The *front-tongue vertical* speech sounds are: /t/, /d/, /n/, /s/, /z/, /ʃ/, /ʒ/, /tʃ/, /dʒ/, /l/, and the retroflex /r/, and the *back-tongue vertical* speech sounds are: /k/, /g/, /ng/, and the back-up /r/ (as well as the retroflex /r/), and the *mid-tongue vertical speech sound* is /j/.

Regarding the /r/ productions, the back-tongue "sides/corners" stabilizes bilaterally on the retromolar pads. The lingual elevation shapes a pharyngeal resonance space for the back-up /r/, and an oral resonance space for the retroflex /r/. (For additional /r/ information, go to SpeechDynamics.com. There you'll find several "R" Therapy Matters blogs, an "R" Article, and *The Easy R* book.)

An important thing to remember therapeutically, is that both types of stabilization must occur, i.e. *external* stabilization on the side teeth/perimeter of the palate and *internal* stabilization via mid-tongue contraction. If the tongue is lowered and at the horizontal midline (not elevated up, or partially up, with the dental arch) and the mid-tongue contracts, the result is something that looks like an /l/ that also typically stabilizes on either the edges of the incisors or the posterior area of the top front-teeth (inter-dental). In essence:

Appropriate positioning (up within the dental arch),
Appropriate lingua-dental-palatal bracing, and
Appropriate mid-tongue contraction must occur simultaneously to generate front-tongue vertical movements for interaction with the opposing articulator.

See the benefit of parsing components then layering them into the production of the speech sound? All the bases are covered that leads to carryover/generalization/transfer.

4. Speech Movements are Refined, Precise and Differentiated

(Fletcher, 1992; Kent, 2004; van Lieshout, 2017)

The size of oral movements—sometimes referred to as amplitude—matters in speech production. In his 2017 study, van Lieshout evaluated the impact of labial and lingual amplitude in the production of bilabials and the tongue for specific VCV strings. The results showed that with small movement amplitudes (where the tongue moved slightly away from the upper arches) there was a decrease in coordination stability and quality of resulting sounds.

In his 1992 book, *Articulation: A Physiological Approach,* Fletcher views speed, positional accuracy, consistency of articulatory movement, and *movement efficiency* [i.e. size of movements and interactive accessibility of the opposing articulators] as hallmarks of speech motor skill.

And that really is an SLP's job: To advance our clients onto and down the path of oral development *via oral differentiation*. Oral differentiation—based in appropriate lingual stabilization, mobilization, and jaw support—results in refined, precise, purposeful movements. Instead of larger, whole-jaw whole-tongue up-down movements as in babbling, the tongue learns to differentiate itself from the jaw and acquire the ability to contract, anchor, and move whole-body or specific lingual parts independently and in coordination with other mouth-parts. The mid-tongue contracts or bunches, the front-tongue stays straight, or elevates or retroflexes, the back-tongue elevates and stabilizes and mobilizes, and the tongue-sides anchor appropriately. The tongue learns to move with *physiological economy.*

In order to generate refined, small movements, there must be stabilization *near the moving part.*

That means, for example in an /s/ production, in order for the front-tongue to sustain itself in space while air courses through, the front-tongue is supported from *nearby mid-tongue contraction and side-tongue lateral bracing.* Biting teeth together to formulate an /s/ does not provide stabilization *near the moving part.*

In addition, Dr. Kent (2004) explains, "The muscles of speech are specialized more for speed than for force and they are capable of precise coordination in the performance of movement sequences." In connected speech, lingual movements must be agile as it tip-toes from placement to placement with rapid precision. Appropriate stabilization enables the precise coordination.

Regarding the tongue-to-opposing-articulator contact, the "touch interaction" is *precise*, meaning, there is minimal surface-to-surface contact. I interpret this to *not* mean that every time we say a /t/, for example, the tongue touches the same place on the alveolar ridge. No doubt there are "zones" or specified areas of contact considered to be appropriate to generate recognizable speech sounds.

5. Intra-Oral Sensory Interaction During Speaking

(McCall, 1969; Gracco, 1972; Nasir and Ostry, 2006; Haggard, et al., 2014; Riquelme, 2015)

Speech production is first and foremost a sensory task; it utilizes intra-oral tactile sensation, proprioception, and auditory sensation (Takayuki, et al., 2009). The mouth, if you will, is a sensing machine. It feels/senses touch and levels of textures and pressure, it perceives spatial qualities, perceives temperatures, tastes, feels pain, and coordinates with the gustatory sense (Howes, et al., 2014). If feels touch and it *touches*.

Functionally, it can be said that

The mouth is the only body part that interacts with itself, meaningfully.
The two forms of interaction are tactile sensation and proprioception.

Generally, I refer to intra-oral sensations as "tactile" and "proprioceptive." While those terms are not technically incorrect, a frequently used term is "somatosensory." The broad view of the somatosensory system is concerned with the conscious perception of touch, pressure, pain, temperature, position, movement, and vibration, which arise from the muscles, joints, skin, and fascia. Unlike the specific receptors: the ears, eyes, and nose.

According to Haggard and de Boer (2014), "*oral* somatosensory awareness refers to the somatic sensations arising within the mouth, and to the information these sensations provide about the state and structure of the mouth itself, and objects in the mouth [such as the tongue, or food, or a thumb]."

Following are three ways to view intra-oral sensation and why it's important. Admittedly each of these topics is a study unto itself, but only brief supportive information by researchers is provided.

1. The importance and utilization of intra-oral somatosensory feedback:

   "Speech production is dependent on both auditory and somatosensory feedback…. Somatosensory information is central to achieving the precision requirements of speech movements. ….Accurate acoustic quality is not the brain's only goal during the motor control of speech—precision in expected somatosensory feedback cues is also an important endpoint." (Nasir and Ostry, 2006.)

   "The mouth has a special status within the somatosensory system. It is one of the most densely innervated parts of the body, in terms of peripheral [surface] receptors. This sensory richness is linked to the key role of oral sensorimotor control in eating, drinking, and speaking…." (Haggard and DeBoer, 2014).

   "Sensory perception is a prerequisite for motor function," (Metcalfe, 2005). Sensation is critical.

2. The levels of perception and reactivity of intra-oral somatosensory feedback (i.e., an individual's personal perception; not merely "do they feel it or not"):

   I pose the question, dare we assume that every person we work with perceives accurate intra-oral, as well as extra-oral sensations?

   In an excellent 2015 study (Riquelme, et al.) they compared the reactivity of children with autism spectrum disorders (ASD) (n=27; average age 6.3 yrs.) with typically developing peers (n=30; average age 6.5 yrs). Children with ASD showed increased pain sensitivity, increased touch sensitivity, and diminished find motor performance and proprioception compared to healthy children.

3. The use of sensory input in therapy (i.e., why and how SLPs apply sensory input to impact a client's motor output):

   We all receive information via our sensations. Therefore, it is the only avenue we SLPs have to impress upon another individual. In therapy, visual and auditory sensory stimuli are often used. But, since none of us can see our mouth first-hand, and speech doesn't become auditory until we say something, my recommendation is to add (to our visual and auditory sensory input) intra-oral tactile input and proprioceptive tasks to our therapy. This provides direct localization of the mouth and mouth-parts for those that need it.

Concerns and Questions

Unlike other sensory systems, such as hearing and vision, that can be assessed and the levels of acuity and perception can be determined and enhanced, do we continue to assume that all children's oral somatosensory system is healthy and in peek, accurate working order? Do we assume there are no individual differences? Even intra-oral taste, another important sense, varies among individuals.

My concern is not whether a child is actually feeling surface sensation, or not, because no doubt they are, unless there has been a significant neuromuscular insult, but I am concerned if they are perceiving interactive touch accurately? Riquelme (2015) calls it "reactivity." So, do reactivity differences correspond with speech impairments? If so, what can be done to calibrate the intra-oral tactile misperceptions, if anything?

Oral Resting Posture: The Harmonizer

The oral mechanism does not function in isolation. The surrounding structures and muscles work together in continuous mutual interaction. The desirable oral resting posture—where the lips, tongue, jaw reside between functions—facilitates an effortless, harmonious functional relationship.

The Positions

(Hanson and Barrett, 1988; Boshart, 2016)

The Desirable Oral Resting Posture: In essence, the lips are closed, the front-tongue is up, the tongue sides touch the side teeth, and jaw is elevated and slightly apart. The exact positions depend on the shape of the dental arch and hard palate, the capability of the soft tissues, the respiratory path, and psychological comfort.

- Lips: The lips are gently closed and held in a state of mild tonus contraction. They exert a small amount of energy to close and generate endurance to remain closed over time.

- Tongue: The surface front tip and blade of the tongue posture on the alveolar ridge and behind the ridge, depending on the hard palate contour. The lateral margins touch the inside of the top back teeth. The tongue maintains its mild tonus contraction over time.

- Jaw: The jaw is elevated but not closed. It maintains a freeway space of 1-3 mm's between the occlusal surfaces of the top and bottom molars. Bilaterally, the mastication muscles sustain a state of mild tonus contraction.

Undesirable Oral Resting Postures: Undesirable oral positions are any characteristics other than closed lips, an elevated tongue with lateral-dental contact, and either a closed jaw, or open lowered jaw. Respiration is an important variable; nose breathing is preferred. Chronic mouth breathing can cause a domino of negative responses. Also, keep in mind, an individual's oral resting posture—no matter the position—is "home-base" for the lips, tongue, and jaw when not in use. Undesirably,

- The lips might be held slightly apart or extremely open (10+ mm's). Open is open. No matter the extent of the parted lips, the oral seal is broken and encourages the tongue to posture in a lowered position.

- The tongue has four (maybe five) position options: on the bottom, in the middle, in the middle and forward, on top, or, one that I've personally only seen twice, contracted and retracted (both were children with Down's syndrome).

- Jaw positioning influences the tongue, i.e. "Wherever the jaw goes so goes the tongue." The consequences of a lowered jaw are obvious: No lip closure, no tongue on top positioning, etc. Air chronically circulates intra-orally; drooling may occur. If the jaw consistently clenches, the temporomandibular muscles may fatigue and over time, pain may occur. Plus, clenching is unhealthy for teeth.

The Rationale and Importance

Admittedly, there is little research directly on the oral resting posture. Most research is based on oral respiration, which indirectly addresses the oral resting posture, which can impact the tongue's stabilization and accessible points of mobilization during speaking. Many therapists have discovered that the oral resting posture plays a critical role in therapy, especially generalization and carryover. Therefore, this important topic is included.

- Hitos, et al., (2012) assessed 439 children, ages 4 to 12 years that breathed through their mouth. They found that 31.2% exhibited speech delays. They concluded that "mouth breathing can affect speech development, socialization, and school performance. Early detection of mouth breathing is essential to prevent and minimize its negative effects on the overall development of individuals."

- Bozzini and Di Francesco (2016) suggest that mouth breathing due to nasal obstruction and/or pharyngeal and palatine tonsil hypertrophy can cause altered positions of the head and mandible and influence the position and tonicity of the tongue. "When they persist, these [abnormal characteristics] modify the equilibrium of muscle pressure on the facial bones and teeth and induce morphological dentoskeletal modifications." E.g., increased lower facial height (which causes labial closure difficulty), reduced posterior airway space and an inferiorly positioned hyoid bone. "Nasal breathing [and a desirable oral resting posture] in children may induce a correction of craniofacial growth and the adequate development of other functions, such as chewing and swallowing." I would also add, speaking.

- Ishida and Hiiemae (2002) state: "The relative positions of the hyoid and mandible directly affect the length and angle of the floor of the mouth on which the tongue mass rides. …As the mandible lowers…so the relative position of the tongue body will be lower relative to the [maxillary] tooth rows." Obviously, this can influence lingual positioning, as well as stabilization and mobilization interaction.

Following are several reasons and benefits to include oral resting posture in speech therapy (listed in no particular order):

- Provides a centralized location (up within the dental arch to one degree or another) for the tongue to interact, and pivot from and to home-base during speaking and swallowing.
- Lateral margins of the tongue rests on the inside of the top, back teeth. This provides easy access for lateral bracing during speaking functions.
- The front-tongue rests on the area of the alveolar ridge where most front-tongue vertical sounds take place; enables easy access.
- Facilitates physiological economy to move and access surrounding points of speaking placements, i.e. "The Principle of Least Effort" (adapted; 1949, Harvard linguist George Kingsley). In most cases, the tongue does not move further than it has to to get the job done.
- An elevated, slightly contracted tongue, postured over time, potentially helps to maintain lingual muscle tone and endurance.
- Provides intra-oral tactile contact. When the jaw is lowered, the lips are parted, the tongue is down, nothing is touching or interacting.
- Lip closure, tongue elevation and a jaw that maintains a 1 to 3 mm freeway space are all in mild tonus contraction; the muscles are physically at-the-ready to move immediately into functions that require greater levels of contraction.
- Jaw elevation and lip closure facilitates nasal breathing.
- Jaw elevation and lip closure facilitates accessible lingua-palatal-dental resting placement and use.
- Jaw elevation and lip closure aids in appropriate cranio-facial bone growth.
- Jaw elevation and lip closure keeps the tongue and saliva inside.
- Lip closure facilitates nasal breathing, i.e. nasal airflow is healthier; filters the air, regulates the temperature, maintains an appropriate humidity level.
- Lip closure helps to maintain anterior dental alignment (anterior dental approximation is important in generating a fricative, hissy /s/; the air courses through the approximated front top and bottom incisors).
- Lip closure helps maintain a moist oral environment; aids in saliva management and taste.

Capability-Based Speech Production Therapy

Seven Principles

The following seven purpose-driven therapy principles are based on the capabilities of the client: physiological, structural, and behavioral. They include the Speech Production Elements that we addressed above.

1. Address Speech Production Elements (generate oral capability, over time)

As we've discussed, the speech act can be parsed into identifiable, tangible components. The capability tasks are systematically determined, practiced, layered, practiced, combined, practiced, and shaped into the speech sound production, and practiced some more. Appropriate articulator stabilization and mobilization are emphasized during the capability-building process, during speech sound production, and during connected speaking.

2. Apply Developmental Differentiation Speech Acquisition Principles

Therapy application takes into account the oral developmental differentiation process. According to Green, et al., (2000) "Motor development may involve *differentiation* (i.e. the modification of a pre-existing behavior into a more specialized ones)." And, "In early motor development, *differentiation* is characterized by increased independence in control of the components involved in the motor task."

There are researchers that view babbling and chewing (only jaw movement was studied) as *not* related to speech development (Moore and Ruark, 1996). Personally, I view babbling, chewing, and swallowing as *functions*. And I prefer to investigate the *physiological components* of the functional movements to determine what capabilities develop—or differentiate—over time. In our field we say that *speech* develops. Speech production, however, is a result of *neuromuscular* development, (Green, et al., 2000).

So, what are the observable characteristics of "development" and how can we apply those in speech production therapy? The differentiation process of the jaw, lips, and tongue progressively refine (to one degree or another) into differentiated stabilization and mobilization components for speech production.

During the first year of development, the jaw is the primary articulator, as evidenced during babbling. Initially, the tongue moves with the jaw, or it moves horizontally. The tongue then develops lateral movements to move food (Evans Morris and Dunn Klein, 1987, p. 56). In many of our speech-children, they continue to produce jaw-driven speech and horizontal tongue movements (inter-dentals, etc.). In therapy, we endeavor to move our speech-kids into stabilized, vertical, refined, precise lingual productions as the jaw remains appropriately supportive.

3. Approach Therapy as a Capability-Building Process that Occurs Over Time

Not all children do or can immediately respond to auditory speech sound stimulation but need personalized instruction, repetition, and time to acquire the capability to produce the speech production. The acquisition of oral capabilities and speech productions is a process. According to Maas, et al. (2008), they explain that "An improved capability for skilled movement should not only be observable during practice but should be retained over time."

Regarding immediate, sound-stim therapy, I'd like to clarify the words we sometime use with our speech kid's and their production efforts: "correct" and "incorrect". When using strictly an auditory approach, the therapist has but one form of sensory input to provide information as to how to produce that speech sound. Then when the child responds and produces an incorrect speech sound, we typically confirm that "it's better" and model the sound (or word) again. Most children, however, have no concept of what that means. Sometimes therapy gets caught in this never-ending cycle and we settle for the child's *acoustic* "close" speech sound production. I know; I used to do that type of (very frustrating) therapy.

Acoustically, a "close" isolated speech sound production is not (usually) appropriately stabilized and mobilized. I suggest, take time to shape and acquire stabilization and mobilization; it's a critical piece.

As you know by now, during connected speech, lingual bracing, is necessity to 1) move and transition from speech sound to speech sound, and 2) establish home-base. The bracing location becomes a point for easy access and controlled speech sound production. It's rather like placing your fingers on the keyboard home row prior to typing**. If the tongue is not appropriately stabilized for all speech sounds—especially the "new" one—carryover/generalization/transfer is problematic.**

4. Include Speech Sound Relevancy Throughout

Ensure the child is aware that the ultimate goal is speech and effective communication. Sousa, in his excellent book *How the Brain Learns* (2017, 5th ed., p. 55) explains, "Information is most likely to get stored if it makes sense and has meaning [relevant to the child]." As you parse and integrate the speech components the client must also be aware of the relevancy connections, otherwise it's empty practice. For example, say, "See? Your hand firmly sits on the table as you write, that's what your tongue-sides do on your side teeth when it says the /s/ sound."

5. Apply Sensory Assists Throughout, as Needed and Tolerated

Sensory stimuli are the only means a therapist has to impact and localize the mouth and mouth-parts, to generate movement. According to Hodson and Paden (1983, page 59), "The child needs to learn what the phoneme 'feels like' as well as what it sounds like…. We used tactile cues as supplements when first presenting the new target…. Tactile cues are simply ways in which the child, through feeling, gain additional information about the image of the target."

Sensory input is powerful and necessary. Visual sensation (e.g. "look at my mouth, look at your own mouth in the mirror") and auditory sensation (e.g. "listen to my speech; listen to your speech; listen to the app, etc.") are most often used. There are two other forms of sensory assists that help the individual focus on the mouth extra-orally and intra-orally: tactile stimuli and proprioception.

A tactile stimulus involves input to surface receptors. *Tactile sensory assists* include localized forms of intra-oral touch (light touch, firm/deep touch, stroking, palpating, and tapping). Variations can be added: tastes, temperature, vibration (do not use vibration with individuals that have seizures). Proprioception is generated internally from within the muscles; it facilitates the kinesthetic sense of movement and positioning. Intra-oral proprioception is best generated by clients closing their eyes and focusing and feeling intra-orally.

A note of caution: Before entering into an individual's mouth, know what mouth-part you're going to interact with, how you will interact (firm-touch, stroking, etc.), what you expect to accomplish, and what tool is best to use to facilitate the sensory assist task.

6. Determine and Compensate for Production Obstacles

(Haruki, et al., *Oral Morphology and Tongue Habits,* 1995)

SLPs work with a variety of individuals who have diagnosed or undiagnosed (idiopathic) neurophysiological, respiratory, oral facial hard-tissue and/or soft tissue obstacles, or oral habits, that impede appropriate speech stabilization and mobilization. Depending on the extent of the obstacle, compensatory speech production may be necessary.

Electropalotography (EPG) studies indicates that some individuals with speech disorders are not able to brace the tongue in the desired manner to form accurate stop closures (Gibbon, 1999; Timmins, et al., 2011). This typically means there might be production obstacles: an excessively narrow or wide dental arch, a cleft palate, or large tonsils displacing the tongue, a restrictive lingual frenum, or neurophysiological issues, etc. I also view acquired adult neuromuscular issues as obstacles to appropriate speech production. It is important to identify and take account production obstacles and their impact on the speech elements.

Liker and Gibbon's (2007) objective was to determine the normal tongue-palate patterns for velar stops. They found that there were differing amounts of contact between speakers. They surmised that some were contacting behind the palatal device, "One explanation for the differences in amount of contact is the interspeaker variations in oral morphology." This is good; rarely do you read how oral structural difference can alter lingual stabilization and mobilization. Most therapists, however, are well-aware.

7. Utilize Practice Principles

According to Maas, et al., (2008), there are several theories of motor control and learning. They state: "…speech production, as a motor skill, is governed by similar principles of motor learning." And, "The distinction between performance during acquisition [practice] and retention/transfer implies that learning, a permanent change in *capability* [their italics] for skilled movement, must be measured by retention and/or transfer tests."

Maas, et al., also state that "Motor skill learning is facilitated by a number of factors pertaining to the structure of practice, stimulus selection, and the nature of feedback…." Following are a couple of principles that Maas, et al., bring forward:

- Pre-practice: Motivation, and understanding the task is important (#4 above, Relevancy), and
- Number of Practice Trials: Although they admit that no empirical evidence is available, they suggest, "…In general a large number of practice trials is beneficial for learning nonspeech motor tasks." I also suggest that it may be prudent to practice the number of repetitions and sets that the client can physiologically do. Unfamiliar oral motor tasks can be fatiguing, therefore, consider doing only the number of repetitions (and sets) they are able to do. Otherwise, as fatigue sets in, the quality of the task diminishes, the child becomes less motivated, and practice benefit lessen.

Regular, capability-based repetitions (and sets) during therapy sessions are important, and if possible, outside of the therapy session, as well. Aim for consistency and continuity.

Bibliography

American Speech-Language-Hearing Association. (1993). *Definitions of communication disorders and variations* [Relevant Paper]. Available from www.asha.org/policy

Boshart, C. (2016). *The Key to Carryover: Change Oral Postures to Fortify Speech Production.* Speech Dynamics, Inc.

Bozzini, MFR, and Di Francesco, RC. (2016). Managing obstructive speech apnoea in children: The role of craniofacial morphology. *Clinics (Sao Paulo), Vol 71 (11),* 664-666.

Brooks, VB. (1983). How posture and movements are governed. *Physical Therapy, Vol 63,* 664-673.

Borghus, J, Hof, AL, Lemmink, KAPM. (2008). The importance of sensory-motor control in providing core stability. *Sports Med, Vol 38 (11),* 893-916. (The Netherlands)

Fletcher, Samuel. (1992). Articulation: A physiological approach. *Singular Publishing Group.*

Evans Morris, S., and Dunn Klein, M. (1987). Pre-Feeding Skills. *Communication Skill Builders, Tucson, AZ.*

Gibbon, FE. (1999). Undifferentiated lingual gestures in children with articulation/phonological disorders. *J of Sp Lang and Hear Research, Vol 42,* 382-397.

Gibbon, F, and Wood, S., (2010). Visual feedback therapy with electropalatography (EPG), *Coarticulation: Theory, data and techniques (pp 229-245).* Cambridge: Cambridge University Press.

Gick, B., and Allen, B. (2013). Speaking tongues are always braced. *The J of the Acoustical Soc of Amer, 134,* 4204.

Gick, B., and Allen, B., Roewer-Desperes, F, Stavness, I. (2017). Speaking tongues are actively braced. *J Sp Lang Hear Res, Vol 60,* 494-506.

Gick, B, Wilson, I, and Derrick, D. (2013). *Articulatory phonetics.* Malden, MA: Wiley-Blackwell.

Gracco, VL. (1992). Characteristics of speech as a motor control system. *Haskins Laboratories Status Report on Speech Research, SR-109/110,* 13-26.

Green, J.R., Moore, C.A., Higashikawa, M., Steeve, R.W. (2000). The physiologic development of speech motor control: Lip and jaw coordination. *J or Sp Lang and Hear Res. Vol 43,* 239-255.

Green, J.R., and Wang, Y. (2003). Tongue-surface movement patterns during speech and swallowing. *J Acoust Soc Am, 113 (5),* 2820-2833.

Grunwell, P. (1990). *Developmental speech disorders.* Edinburgh: Churchill Livingstone.

Haggard, P, and de Boer, L. (2014). Oral somatosensory awareness. *Neurosci and Biobehavioral Revs, Vol 47,* 469-484.

Hanson, ML, and Barrett, RH. (1988). Fundamentals of orofacial myology. *Springfield, IL: Charles C Thomas Pub.*

Haruki, T., Kanomi, R., Morita, H., Kawabata, J. (1995). Oral morphology and tongue habits. *Int J Orofacial Myology, Vol 21,* 4-8.

Hitos, SF, Arakaki, R, Sole, D, Wecks, LLM. (2012). Oral breathing and speech disorders in children. *J Pediatr (Rio J), Vol 89 (4),* 361-365.

Howes, PD, Wongsriruksa, S, Laughlin, Z, Witchel, HJ, Miodownik, M. (2014). The perception of materials through oral sensation. *PLoS One, Vol 19;9(8),* 1-12.

Ishida, R, Palmer, JB, Hiiemae, KM. (2002). Hyoid motion during swallowing: Factors affecting forward and upward displacement. *Dysphagia, Vol 17 (4)*, 262-272.

Kent, R.D., (2004). The uniqueness of speech among motor systems. *Clin Linguistics & Phonetics, Vol 18, (6-8),* 495-505.

Kent, R., (2015). Nonspeech Oral Movements and Oral Motor Disorders: A Narrative Review. *Amer J of Sp-Lang Path, Vol 24,* 763-789.

Kier, W.M., Smith, K.K. (1985). Tongue, tentacles and trunks: The biomechanics of movement in muscular-hydrostats. *Zoological Journal of the Linnean Society, 83,* 307-324.

Hardcastle, W.J., Morgan Barry, R.A., Clark, C.J. (1987). An instrumental phonetic study of lingual activity in articulation-disordered children. *J of Sp Hear Res., Vol 30,* 171-184.

Kent, R.D. (2004). The uniqueness of speech among motor systems. *Clinical Linguistics & Phonetics, Vol 18, (6-8),* 495-505.

Kent, R.D. (2015). Nonspeech oral movements and oral motor disorders: A narrative review. *Amer J of Sp-Lang Path. Vol 24,* 763-789.

Ladefoged, P. and Maddieson, I. (1996). *The Sounds of the Worlds Languages.* Oxford Blackwell.

Lee, A, Gibbon, FE, and Oebels, J. (2015). Lateral bracing of the tongue during the onset phase of alveolar stops: An EPG study. *Clinical Linguistics & Phonetics, Vol 29 (3),* 236-245.

Luo, S., Liu, Y., Shamei, A., Schellenbert, M., Luszczuk, M., Gick, B. (2018). Tongue bracing under bite block perturbation. *Canadian Acoustics, Vol 46, (4),* 54-55.

Lof, G. (2017). Tools for Skeptical Thinking; Evaluating Science and Pseudoscience in Speech-Language Pathology (pages 2-13); Logic, Theory, and Evidence Against the Use of Nonspeech Oral Motor Exercises (NSOME) to Change Speech Sound Productions in Children

Maas, E. (2017). Speech and nonspeech: What are we talking about? *Int J Speech Lang Patholo. Vol 19 (4),* 345-359.

Maas, E., Robin, D.A., Austermann Hula, S.N., Wulf, G., Ballard, K.J., Schmidt, R.A. (2008). Principles of Motor Learning in Treatment of Motor Speech Disorders. *Amer J of Sp-Lang Path., 17,* 277-298.

McCall, GN. (1969). The assessment of lingual tactile sensation and perception. *J of Sp and Hear Dis, Vol 34 (2),* 151-156.

McLeod, S. (2011). Speech-language pathologists' knowledge of tongue/palate contact for consonants. *Clinical Linguistics and Phonetics, 25,* 1004-1013.

Metcalfe, JS, McDowell, K, Chang, TY, Chen, LC, Jeka, JJ, Clark, JE. (2005). Development of somatosensory-motor integration: An event-related analysis of infant posture in the first year of independent walking. *Dev Psyhobio. Vol 46,* 19-35.

Moore, C., and Ruark, J. (1996). Does speech emerge from earlier appearing motor behaviors? *J of Sp and Hear Res., 39,* 134-1047.

Nasir, SM, and Ostry, DJ. (2006). Somatosensory precision in speech production. *Current Biology, Vol 16,* 1918.

Parker, F. (1976). Distinctive features in speech pathology: phonology or phonemics. *J Sp Hear Disorders, Vol 41 (1),* 23-39.

Riquelme, I, Hatem, SM, Montoya, P. (2016). *Neural Plasticity. Vol 2016, Article ID 1723401,* 9 pages.

Scripture, EW. (1912). *Stuttering and lisping.* New York: MacMillan.

Stolar, S, and Gick, B. (2013). An index for quantifying tongue curvature. *Canadian Acoustics, Vol 41 (1),* 11-15.

Stone, M., Faber, A, Raphael, LJ, and Shawker, TH. (1992). Cross-sectional tongue shape and linguopalatal contact patterns in /s/, "sh", and /l/. *Journal of phonetics, 20,* 253-270.

Stone, M., Lundberg, A. (1996). Three-dimensional tongue surface shapes of English consonants and vowels. *Journal Acoustic Soc. Am. 99 (6),* 3728-3737.

Takayuki, I., Tiede, M., Ostry, D.J. (2009). Somatosensory function in speech perception. *Proc Natl Acad Sci U.S.A., 106, (4),* 1245-1248.

Takemoto, H. (2001). Morphological analyses of the human tongue musculature for three-dimensional modeling. *J Speech Lang Hear Res, 44,* 97-107.

Tasko, SM., McClean, MD. (2004). Variations in articulatory movement with changes in speech task. *J of Sp Lang, and Hear Res. Vol 47,* 85-100.

van Lieshout, PHHM, (2017). Coupling dynamics in speech gestures: amplitude and rate influences. *Exp Brain Res, 235 (8),* 2495-2510.