Must-have features of CAS Intervention

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Disclosures

- Ms. Caspari receives compensation as an invited speaker to ASHA Connect
- Ms. Caspari is an advisory council member for the Apraxia Kids organization (formerly CASANA) and receives no compensation as a board member

Learning Objectives

- Use movement-based cues (rather than sound-based cues) specific to a child's production errors
- Administer an evidence-based treatment approach for children with CAS
- List creative ways to increase practice trials for children with CAS in the school setting

Overview

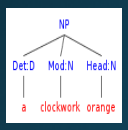
- Motor-Based Interventions for CAS
- Dynamic Temporal and Tactile Cueing (DTTC)
- Rapid Syllable Transitions (ReST)
- Biofeedback

- ✓ ***Motor-Based Interventions for CAS***
- Dynamic Temporal and Tactile Cueing (DTTC)
- Rapid Syllable Transitions (ReST)
- Biofeedback

CAS is a motor-based ("movement") disorder

Cognition

Ideas



Language

Word Retrieval | Phonological Mapping | Syntactic Framing

Motor Speech

Motor Planning | Motor Programming | Motor Execution

(Caruso & Strand, 1999)

Errored movements cause speech errors

- It's because we MOVE incorrectly (wrong place, wrong time, or wrong speed) that CAUSES the segmental and prosodic errors we see in CAS

Vowel errors
Inconsistencies
Segmentation between syllables
Stress errors

Motor-based interventions for CAS

- Therefore, our goal in treatment is to…
- Improve "movement gestures" for speech

✓ Must-have feature #1

- Goal is to improve ***movement*** *gestures* in speech
  - Want the child to be able to produce the fluent, coordinated speech movements needed for increasingly longer and more complex syllable shapes
  - Consonants are part of the determination of accurate movements, but even IF consonants are correct, can still have inaccurate movement between sounds and syllables
    - Vowel errors
    - Segmentation between sounds and syllables
    - Stress errors
    - Voicing contrast errors
    - Sound additions…

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MOVEMENT based goals not SOUND-based goals

An analogy

Flute lesson

- Using a few target songs
- Carefully selected in terms of difficulty
- With the GOAL of being able to help the child become more adept at coordinating the movements of respiration, finger /lip/tongue movements required to produce fluent music

CAS Speech lesson

- Using a few target utterances
- Carefully selected in terms of difficulty
- With the GOAL of being able to help the child become more adept at coordinating the movements of respiration, phonation and articulation required to produce fluent speech

Motor-based interventions for CAS

- In order to help improve "movement gestures" for speech
- Need to understand how skilled movements are learned

Principles of motor learning

Motor-based interventions for CAS

- So, motor based speech disorder
- Principles of motor learning in treatment

How to practice to learn a motor skill (Schmidt &Lee, 2005)

Principles of motor learning

Summary Principles of Motor Learning

Principle	Retention
Practice amount	Large
Motivation	High
Understand task	Understand what is being asked of you and why
Task specificity	What you practice is what you learn
Optimum challenge level	Not too hard, not too easy

Principles of motor learning

Summary Principles of Motor Learning
Adapted with permission from Ruth Stoeckel, Ph.D.

Principle	Acquisition	Retention
Practice Distribution	Mass	Distributed
Practice Variability	Consistent context, consistent prosody, pitch, rate	Varied context, varied prosody, pitch, rate
Practice Schedule	Blocked, predictable order	Random unpredictable order
Feedback Type	Knowledge of performance	Knowledge of results
Feedback Frequency	Often, immediate	Inconsistent, delayed
Rate	Slow	Normal, varied
Attention and Focus	Internal	External

Current research focuses on application of the PML to the treatment of CAS

- Edeal, DM, & Gildersleeve-Neumann, CE (2011)
- Hula, Robin, Maas, Ballard, & Schmidt (2008)
- Maas, E., Butalla, CE, & Farinella, KA (2012)
- Maas, E., & Farinella, KA (2012)
- Skelton, SL, & Hagopian, AL (2014)

Research findings (Maas et al 2014)

- Summary PML
  - Motor-based therapy approaches have been found to produce gains in speech production abilities in children with CAS
- Across studies: Ingredients that are likely to contribute to speech improvements in children with CAS
  - High amount of practice
  - Relatively small set of therapy targets – allows for more practice trials of each
  - Provision of knowledge of performance vs. knowledge of results feedback
  - Use of alternative feedback modalities (visual, tactile, etc…)
  - Homework component – distributed practice

Must-have feature #2

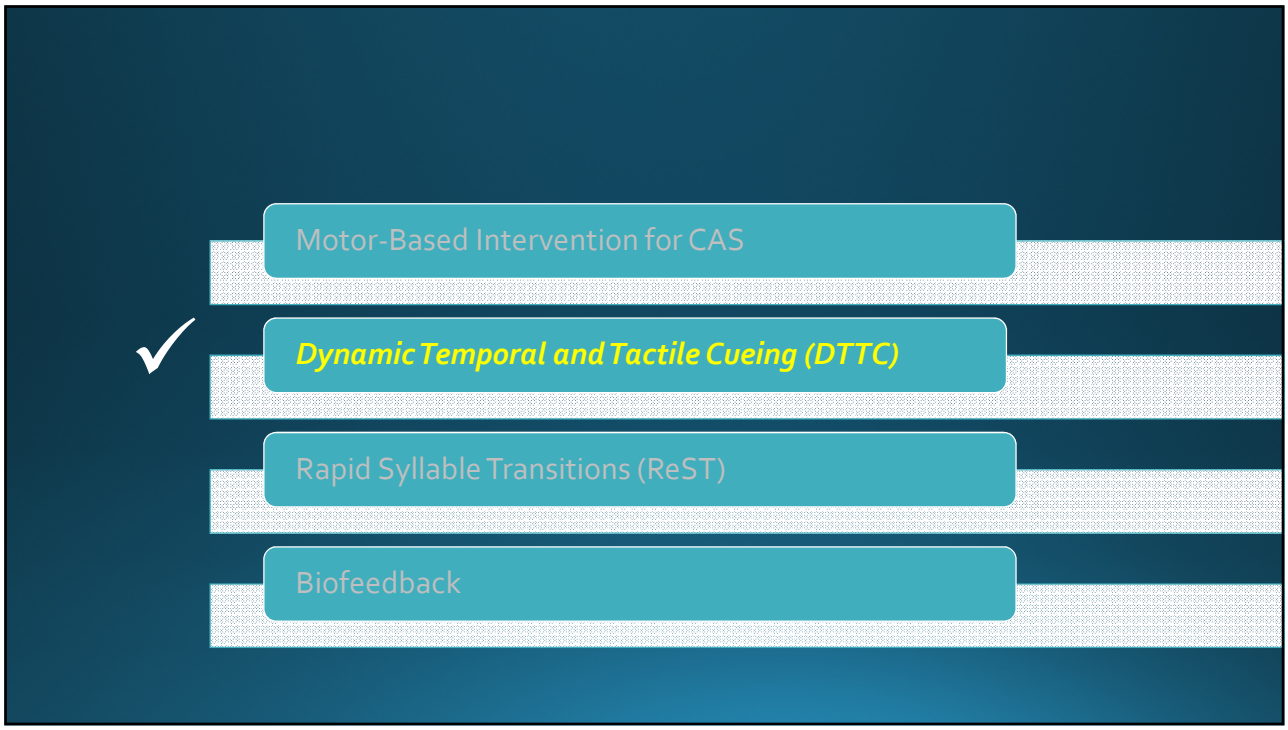
✓

- Incorporate principles of motor learning in ways thought to be helpful for motor learning (Maas, et al, 2008; Maas, et al. 2014)
  - High amount of practice trials
  - Utilize alternate feedback modalities
  - Address the dichotomy of acquisition factors (mass, blocked, constant, and high frequency and immediate knowledge of performance feedback) vs. retention factors (distributed, random, variable practice, high number of trials, and low-frequency end delayed knowledge of results feedback)

Evidence-based interventions

Must-have features

- ✓ Is the goal of the approach MOVEMENT based?
  - Addresses movement gestures between sounds and syllables (not just consonant accuracy)
    - Vowel errors
    - Segmentation between sounds and syllables
    - Stress errors
    - Voicing contrast errors
    - Sound additions…
- ✓ Have the principles of motor learning been considered?
  - High amount of practice trials
  - Utilize alternate feedback modalities
  - Address the dichotomy of acquisition factors vs. retention factors



DTTC (Strand, Stoeckel & Baas, 2006; Yorkston et al, 2010; Maas, et al, 2014)

- Repetitive intensive drill - of increasingly longer real words and phrases (functional vocabulary used as targets)
- Incorporates principles of motor learning – all acquisition and motor learning strategies
- Targeted to young (3-8 years), more severely impaired children with CAS
- Has strongest evidence base for use with children with CAS
  - 6 studies
  - 3 independent labs
- Across DTTC treatment studies, the greatest gains occurred when:
  - Targets were functional
  - Treatment was frequent
  - Production frequency was highest
  - Motivation was highest

DTTC (Strand, Stoeckel & Baas, 2006; Yorkston et al, 2010)

- Integral stimulation type speech therapy – involves imitation ("watch me, listen, and do what I do")
- This means:
  - Direct type of therapy (not indirect)
  - Child understands what is being asked and why
    - They need to know they are working on "*movements*" vs. sounds

DTTC (Strand, Stoeckel & Baas, 2006; Yorkston et al, 2010)

- Target utterances are real words/phrases that are functional and meaningful to the individual child

I DO IT

Tony

She went

- This means
  - Ask teachers and parents to generate laundry list of motivating, functional words and phrases
    - Motivation is increased
    - Spoken communication becomes quickly functional
    - Can target specific syntactical forms
    - Can target curricular vocabulary

DTTC (Strand, Stoeckel & Baas, 2006; Yorkston et al, 2010)

- Targets utterances are carefully selected to meet criteria for optimum challenge level in terms of sounds, syllable length and phonotactic structure

"Tony"
4 movements/sounds
Simple syllable structure
Cvcv
IPC = 0

"invitation"
9 movements/sounds
More complex syllables structure
VCCVCVCVC
IPC = 6

- This means:
  - Select from the laundry list, targets that meet parameters for optimum challenge level
    - Phonetic inventory
      - Sounds the child already can produce
      - Sounds the child is stimulable for
      - Sounds that are early developing and highly visible
    - Syllable shape beginning where child is breaking down on motor speech assessment
    - Phonotactic complexity – IPC

DTTC (Strand, Stoeckel & Baas, 2006; Yorkston et al, 2010)

- Repetitive intensive drill of functional vocabulary is a key aspect and is intended to increase generalization of motor patterns to functional communicative settings

"Tony"
"Tony"
"Tony"
"Tony"
"Tony"

- This means:
  - Relatively small set of targets at any one time so you can get more practice trials of each one
    - 4-6 targets early in treatment or for severe disorders
    - 10-15 targets later in treatment or for more mild disorders
  - Activities in therapy session have to allow for lots of practice, and reinforcers should be quick

DTTC (Strand, Stoeckel & Baas, 2006; Yorkston et al, 2010)

- The child is encouraged to **watch the clinician's mouth** when she model's a target , especially when first working on a target, to facilitate attention and focus to the speech movement gestures

Principle	Acquisition	Retention
Practice Distribution	Mass	Distributed
Practice Variability	Consistent context, consistent prosody, pitch, rate	Varied context, varied prosody, pitch, rate
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DTTC (Strand, Stoeckel & Baas, 2006; Yorkston et al, 2010)

- Importance of mirror neurons in motor learning (Rizzolatti et al,1996)
  - Neuron X fired every time the monkey grabbed for a peanut
  - Neuron X = motor planning neuron essential to motion
  - Human grabbed the peanut while the monkey was watching
  - Neuron X fired IN THE MONKEY but the monkey was not moving – just watching
  - Motor neurons essential for movement fire when just watching a motor movement
  - Similar mirror neuron system found in humans

This means: Watching is just like doing it yourself

DTTC (Strand, Stoeckel & Baas, 2006; Yorkston et al, 2010)

- The child is encouraged to imitate a slower speech rate at first and as motor planning improves, the rate is slowly increased to conversational rates

- This means:
  - Clinician's model is slow, but not too slow at first
    - Try to maintain coarticulation/fluency of entire movement gesture – do not break into parts or segment

DTTC (Strand, Stoeckel & Baas, 2006; Yorkston et al, 2010)

- Practice schedule, and variability are adjusted throughout progression of each target in order to facilitate motor learning

Sammy		Sammy
Sammy		Hi mom
Sammy		I do it
Sammy	VS.	Hi mom
Hi mom		I do it
Hi mom		Sammy
Hi mom		Sammy

- This means:
  - Blocked, constant practice at beginning of treatment, or for severe disorders
  - Random, varied practice as targets become mastered later in treatment, or for milder disorders

DTTC (Strand, Stoeckel & Baas, 2006; Yorkston et al, 2010)

- Accurate movement gestures during speech are shaped through multimodal cueing techniques (visual, verbal, tactile cues)
- The cues change from trial to trial based on the errors the child makes
- Feedback is systematically altered to facilitate motor learning (knowledge of performance vs knowledge of results)

- This means:
  - Listen to child's attempt
  - Identify error
  - Provide cue based on error
    - At first be specific – consider movement-based words for verbal cues
    - Later be more general
  - Increase amount or intensity of cues as needed to achieve accurate movement (verbal, gestural, tactile) – do not want to practice incorrect movement gestures

Movement based cue

- Target is /du/ ("do")
- Child says /bu/ ("boo")
- Think about HOW they should move differently to achieve a more accurate production:
- Movement based cue???

DTTC (Strand, Stoeckel & Baas, 2006; Yorkston et al, 2010)

- Practice giving movement based cues for vowel errors
- The target is "MOVE" /muv/
- The child says "MEEV" /miv/

- What is an appropriate movement-based cue?

A – Pull your tongue back

B – Round your lips

C – Round your lips and pull your tongue back

D – None of the above

E – Any of the above

DTTC (Strand, Stoeckel & Baas, 2006; Yorkston et al, 2010)

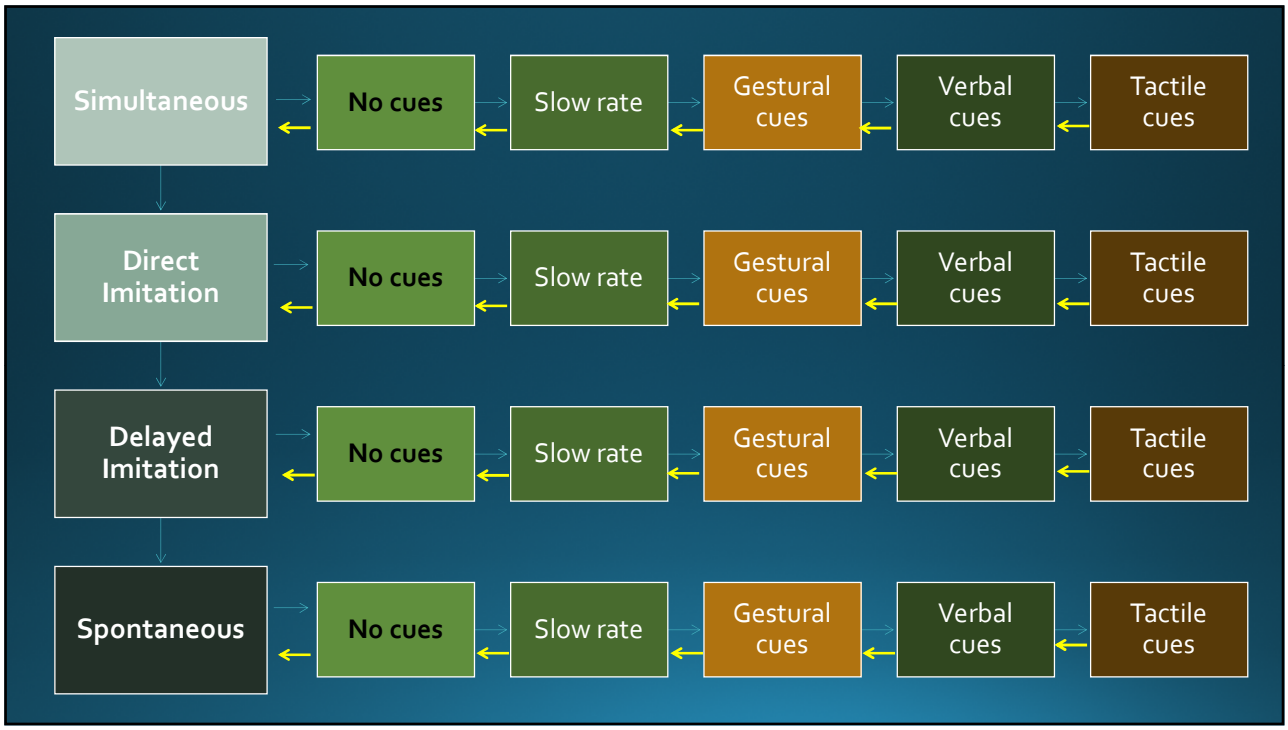
- Cues are gradually faded and the time from presentation of the model to the child's response is lengthened as the child progresses to support independence

Therapist: Say 'Hi mom'

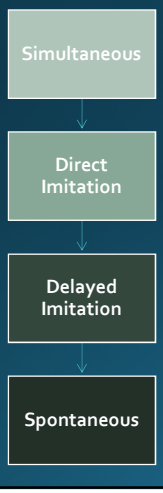
---- PAUSE ----

Child: "Hi mom"

- This means:
  - Fade cues systematically to enable the child to hold onto accurate productions
    - Frequency of cues/feedback
    - Timing of feedback
  - Add pause between our model and the child's production, ultimately fading to spontaneous productions where there is no model



DTTC



- Move ahead in the levels once the child has
  - No articulatory errors
  - Normal rate
  - Good prosody

DTTC

- Move back a level anytime if needed
  - Goal is to get as many "correct" practice trials as possible
  - Perfect practice makes perfect
  - Do not want to practice the "incorrect" movement gesture – negative learning

DTTC (Strand, Stoeckel & Baas, 2006; Yorkston et al, 2010)

- Distribute practice over time, environments, and contexts

- This means:
  - Frequent (3-5X/wk) short (30 min) sessions to allow for mass and distributed practice of targets over time within sessions
  - Target utterances are sent home and into the classroom for practice as they achieve mastery within speech sessions

Ideas for practice in the schools

- In the classroom
  - SLP consult with teacher to identify target words and phrases visually represented in the classroom that the child can say
    - Stickers on curriculum words around the room
      - Letter names
      - Numbers
      - Sight words

Ideas for practice in the schools

- Ideas for practice in the classroom
  - SLP work with teacher to identify curriculum words to work on in speech therapy in advance of lectures to help the child be able to more fully participate in discussions
    - Science lecture on "stalagmites" and "stalagtites"

Ideas for practice in the schools

- Ideas for practice during unstructured times
  - If the child has an aide, the SLP can collaborate with the aide to obtain functional words and phrases that would be useful in social interactions with peers
  - Once they are mastered and are ready for practice outside of the speech room, the aide can elicit them during free times – lunch, recess
    - "Want to play tag?"
    - "You're it."

Ideas for practice in the schools

- Children with CAS are at increased risk for having reading and writing difficulties (ASHA, 2007)
- SLP collaborate with special educator/reading specialist
  - Select target words that have likelihood of being produced accurately
    - Target words controlled for 'sounds' already in child's phonetic inventory
    - Target words controlled for length and complexity
  - During reading instruction, minimize or eliminate verbal productions
    - When asking the child to produce words orally during reading instruction, promote "accurate" movement gestures
      - Do NOT break utterances into individual segments (sounds or syllables) – rather, practice as one continuous movement gesture

DTTC Highlights

Therapy Highlights
Dynamic Tactile and Temporal Cueing – DTTC
(Strand & Stoeckel, Baas, 2006, Yorkston et al, 2010)
Incorporating the Principles of Motor Learning*

Principles/Ingredients likely to contribute to speech improvements in children with CAS (Maas et al, 2014)
High amount of practice Relatively small set of therapy targets Provision of knowledge of performance vs. knowledge of results feedback Use of multisensory feedback modalities Homework component
Consider individual needs, motivations and desires of each child when making treatment decisions

I. Decide on target words/phrases – optimum challenge level
   a. Phonetic inventory from assessment, including stimulability information
   b. Sounds that are early developing and highly visible
   c. Syllable shapes based on assessment results – level at which motor speech is breaking down
   d. Phonotactic complexity
   e. Functional and motivating – list from parents/teachers
   f. Consider movement gestures related to place, manner, voicing features
II. Decide how many targets to put into practice
   a. Fewer for children with severe disorders or early in treatment (4-6)
   b. More for children with less severe disorders or later in treatment (10-15)
III. Establish goals

Therapy Highlights
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II. Decide how many targets to put into practice
   a. Fewer for children with severe disorders or early in treatment (4-6)
   b. More for children with less severe disorders or later in treatment (10-15)

III. Establish goals
   a. Overall goal is for child to produce entire movement gesture accurately of increasingly longer and more phonetically complex targets
      i. Not just consonant accuracy – but ALSO vowel accuracy, coarticulatory transitions between sounds and syllables (no segmenting/pausing), prosody/stress
   b. Establish criteria in order to ensure motor learning/prevent regression – cumulative accuracy

IV. Decide on level of service
   a. Frequent, short sessions with a high rate of repetition to facilitate motor learning – 3-5, 30-minute sessions/week

V. Identify activities to engage the child in during the therapy session
   a. Motivating to that particular child
   b. Turns are quick to facilitate lots of speech practice trials
   c. Reinforcers, if used, are quick to facilitate lots of speech practice trials

VI. Decide on practice schedule
   a. Blocked, constant, mass practice when first working on a difficult target
   b. Random, varied, distributed practice once target is nearing mastery

VII. Within session

a. Make sure child understands what is being asked of him/her and why – they need to know they are working on *movements* vs. sounds
b. Focus of session is on getting as many accurate practice trials of each target as possible
c. Clinician model
    i. Encourage child to watch your mouth as you model the target – mirror neurons
    ii. Slow rate of model, but not too slow (and do not segment) at first to provide support, then move to faster, more natural and varied rate once target is nearing mastery
d. Adjust timing of model to ensure "correct" movement gestures are maintained
    i. Simultaneous – Direct imitation – Delayed imitation – Spontaneous: Move to simultaneous productions when needed to keep productions accurate; then fade timing of your model (withdraw supports) by moving to direct imitation – then delayed imitation – then simultaneous as child progresses in therapy
e. Adjust cues to facilitate motor learning
    i. Add cues as needed to keep productions accurate
    ii. Fade cues slowly to keep productions accurate
    iii. Provide frequent, specific, internally-focused, movement-based cues at first (knowledge of performance) to help with acquisition
    iv. Use less frequent, more general, outcome oriented cues later (knowledge of results) to help with retention/motor learning

VIII. Motor learning/retention

a. Distribute practice across time, environments and contexts in order to facilitate motor learning
    i. Send targets into home and classroom once they are nearing mastery within speech sessions

*Motor-based therapy approaches have been found to produce gains in speech production abilities in children with CAS (Murray et al 2014). However, the few studies that have looked at how the principles of motor learning hold up in treatment of children with CAS have shown mixed results, and not all children respond to a given practice condition manipulation in the same way. (Maas et al, 2014).

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 (3); Strand, E. A., Stoeckel, R., & Baas, B. (2006). Treatment of Severe Childhood Apraxia of Speech: A Treatment Efficacy Study. *Journal of Medical Speech-Language Pathology, 14*, (4) 297-307; Yorkston, KM, Beukelman, DR, Strand EA, Hakel, M. (2010). *Management of Motor Speech Disorders in Children and Adults – Third Edition*. Texas: Pro-Ed.

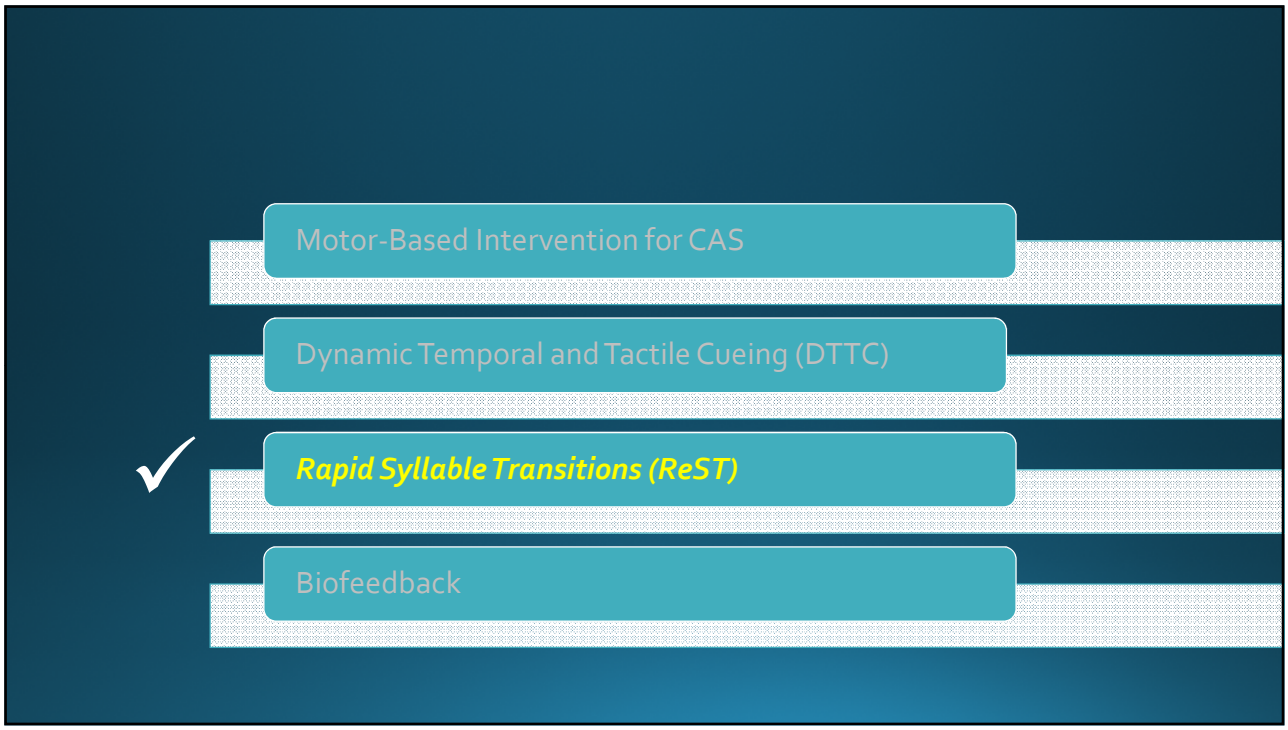
Summary DTTC

(Strand, Stoeckel & Baas, 2006; Yorkston et al, 2010; Maas, et al, 2014)

- ✓ Repetitive intensive drill - of increasingly longer real words and phrases (functional vocabulary used as targets)
- ✓ Focuses on shaping all aspects of movement gestures during speech (consonant and vowel accuracy, coarticulation, prosody/stress…)
- ✓ Incorporates principles of motor learning – all acquisition and motor learning strategies
- Targeted to young (3-8 years), more severely impaired children with CAS
- Has strongest evidence base for use with children with CAS
  - 6 studies
  - 3 independent labs
- Across DTTC treatment studies, the greatest gains occurred when:
  - Targets were functional
  - Treatment was frequent
  - Production frequency was highest
  - Motivation was highest

How DTTC differs from treatment for articulation and phonological disorders

	DTTC	Articulation	Phonological
Number of stimuli	Fewer	Many	Many
Stimuli parameters	Length and phonotactic complexity of utterance (using sounds that are already mastered)	Sounds in error	Phonological patterns in error
Goal	Produce entire utterance correctly (eg produce movement gestures in CVC words accurately so there are no errors in sounds (C&V), sequencing, coarticulation or prosody)	Produce target sound correctly (eg /s/ produced accurately in initial, medial and final word position)	Demonstrate knowledge of the rule (eg final consonants added in words that should have final consonants)



ReST (Murray, McCabe & Ballard, 2015)

- Rapid Syllable Transition (ReST)
  - Repeated productions of multi-syllabic non-words – surrogate for novel vocabulary
  - Focuses on principles of motor learning that facilitate retention (but also includes pre-practice which focuses on "performance")
    - Large practice amount
    - Random practice schedule
    - Variable practice
    - Reduced feedback frequency
  - May be best for older CAS children (4-12 years) with milder, idiopathic impairment
  - Relatively strong evidence base for CAS treatment (Maas, et al, 2014)
    - Has fewer studies than integral stimulation, but one study is RCT – higher level of evidence
    - All studies done by one research group
    - N=3 children ages 7;8 – 10;10

ReST

(Murray, McCabe & Ballard, 2015)

- Rapid Syllable Transition (ReST)
  - Addresses
    - (a) segmental (sound) consistency through improving accuracy (SOUNDS)
    - (b) rapid and fluent transitions from one segment and syllable to the next (SMOOTHNESS)
    - (c) accurate production of lexical stress, and demands accuracy on all three aspects simultaneously (BEATS)

ReST

(Murray, McCabe & Ballard, 2015)

- Practice schedule
  - 10-12 1-hour sessions across 3 weeks
  - Spread 10-12 hours over 6 weeks

ReST

(Murray, McCabe & Ballard, 2015)

- 20, 2-syllable or 3-syllable non-words (start at level just above client's abilities on assessment)
- Advance from 2-syll, to 3-syll, to 3-syll as final noun within a carrier phrase (e.g., "Can I have a ba**gu**ti?")
- 10 have WS; 10 have SW

ReST

(Murray, McCabe & Ballard, 2015)

- Use of pseudowords – reduces the linguistic load

ReST

(Murray, McCabe & Ballard, 2015)

- "All pseudowords had a high phonotactic probability and were orthographically biased to facilitate selection of the targeted stress pattern in reading aloud"

ReST

(Murray, McCabe & Ballard, 2015)

- Consonants and vowels in pseudowords are individualized for each child

ReST

(Murray, McCabe & Ballard, 2015)

- Training/Prepractice
  - "*minimal internal reference of correctness*" -- This means that they need to understand what is required of them but they do not need a high degree of success in this phase initially.
  - Clinician models for student and provides specific KP feedback after every production
    - SOUNDS - phonetic placement cues
    - BEATS – prosodic cues - tapping out the stress pattern (e.g. for the prosodic pattern: "Great soft then strong beat, well done" or "you said all strong beats."); visual cues (long tall block for stressed, short small block for unstressed
    - SMOOTHNESS - visual cues for fluency (no segmenting)
  - Fade cues until student can produce 5 correct pseudowords of any of the nonsense words in a row without a model
    - Once any 5 pseudowords are produced correctly the session moves to the practice phase

ReST – Pre-practice

(Murray, McCabe & Ballard, 2015)

- Clinician: Tell the child they need to exactly match how you say the words
- Explain
  - Sounds
  - Beats
  - Smoothness

ReST – Pre-practice

(Murray, McCabe & Ballard, 2015)

- Clinician: Show the child the card

keeda

- Say the word: "/kidə/"

- Child: Say the word with the stress on the correct syllable and the sounds all correct but with a pause between syllables "/ki.də/"

ReST – Pre-practice

(Murray, McCabe & Ballard, 2015)

- Say the word: "/kidə/"
- Child says "/ki.də/" with a pause between syllables

- What term would you use to cue the child using the ReST program?

A – Beats

B – Smoothness

C – Sounds

ReST – Pre-practice

(Murray, McCabe & Ballard, 2015)

- Clinician: Show the cue card for

  smoothness

- Provide any/all specific cues to blend the syllables together without segmenting

- Child: Respond to the cues with a correct production:

  "/kidə/"

ReST – Pre-practice

(Murray, McCabe & Ballard, 2015)

- Clinician: Fade cues until student can produce 5 correct pseudowords in a row without a model

keeda

deba

fadee

feka

bade

ReST – Practice

(Murray, McCabe & Ballard, 2015)

- Practice
  - Pseudowords are presented "orthographically" (written on cards)
    - With clinician model!
  - 20 pseudowords – one trial each of each psuedoword, in random order
    - If no correct responses in 2 consecutive blocks, insert an additional block of training
    - After each block, there is a 2 min break to play a game
  - KR (or "right" "wrong") feedback provided after 3-5 second delay between response and feedback for all
    - at first on 9/10 trials and at end only 1/10 trials – average 5/10 trials
  - Go through the 20 pseudowords 4 more times (5 blocks total)
  - Goal is 80% accurate with no cues across 100 trials (20 treated items, 5X/each) over 2 consecutive sessions (then advance to next level)

ReST – Practice

(Murray, McCabe & Ballard, 2015)

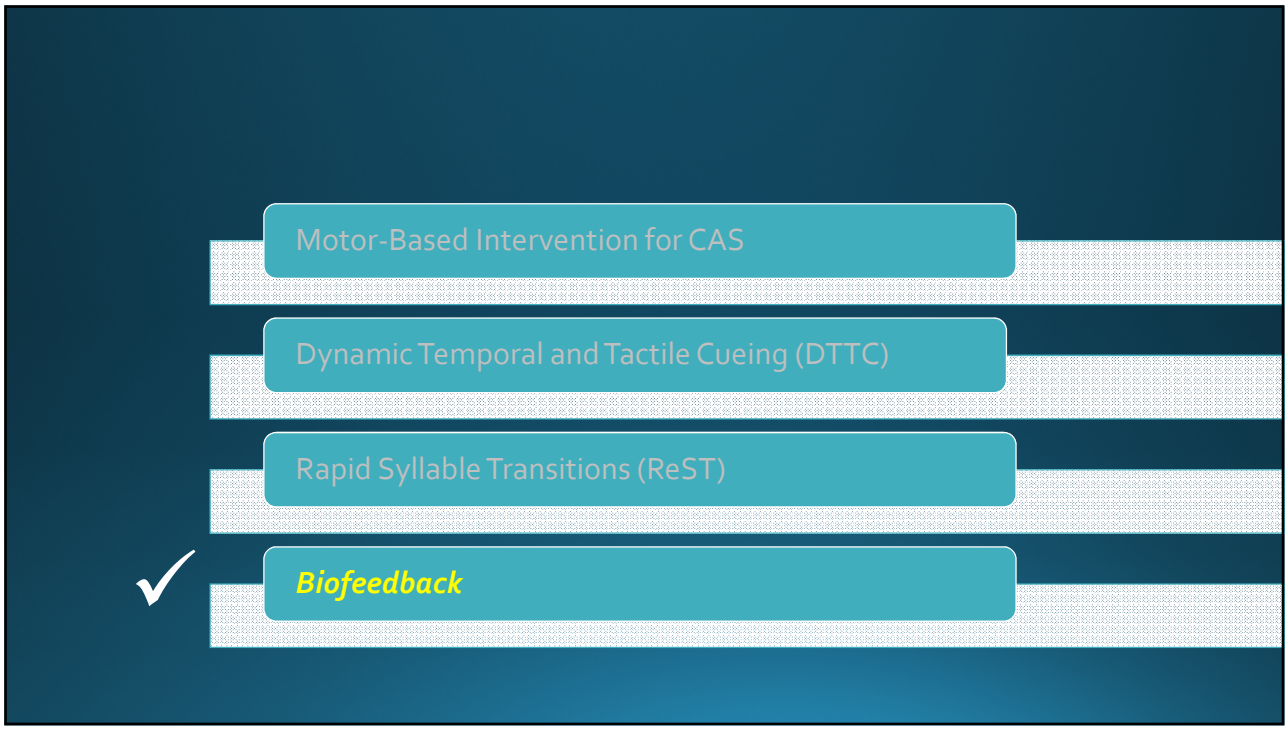
- Clinician: Show and say word
  "/kidə/" keeda
- Pause while you transcribe child's response
- Provide right/wrong feedback only verbally "That's right/wrong" on 16 of 20 words
- Go on to next word (20 words total)
  "/dəbɔ/" deba
- Child: Repeat each word once

Summary ReST

- ✓ Repetitive intensive drill - of increasingly longer pseudo words and phrases
- ✓ Focuses on shaping all aspects of movement gestures during speech (sounds, beats, and smoothness)
- ✓ Incorporates principles of motor learning – acquisition principles in pre-practice and retention principles in practice phase
- Targeted to older (4-12 years), less severely impaired children with CAS
- Has relatively strong evidence base for use with children with CAS

DTTC and ReST freely available

- Descriptions and video examples
  - DTTC – Once Upon a Time Foundation - www.childapraxiatreatment.org
  - ReST – University of Sydney - http://sydney.edu.au/health-sciences/rest/



Biofeedback

- Biofeedback in the treatment of CAS (Maas, et al, 2014)
  - Uses visual feedback of speech movements
    - Electropalatography – tongue to palate movements
    - Ultrasound – tongue movements
  - May be best for older children
  - No studies yet on "acoustic spectral" biofeedback for CAS
    - Spectral biofeedback
    - Linear predictive coding (LPC) spectrum

Biofeedback

- Electropalatography (Lundeborg, McCallister, 2007)
  - Customized retainer with different electrodes in different locations on the palate
  - Data sent through microprocessor to a computer
  - Software shows tongue-to-palate contact on computer screen

Biofeedback

- Ultrasound (Preston, Brick & Landi, 2013)
  - Ultrasound transducer is connected to a laptop
  - Transducer then placed under the child's chin with gel – child can hold it or lean on it on a stand
  - Child is oriented to image
  - Slow speech rate used
  - Visual display provides real-time feedback about tongue movements

Biofeedback

- Spectral biofeedback (non-CAS) (Shuster, Ruscello, Toth, 1995)
  - Use spectrograph like Praat
  - Use external mic
  - Clinician models target
  - Image of formants displayed on spectogram
  - Child is oriented to image
  - Child tries to match their own production to the model formants – but ***not real-time***

Biofeedback

- Praat use for children with CAS - free downloadable speech analysis program from the University of Amsterdam - downloadable from: http://www.fon.hum.uva.nl/praat/
  - Vowels
  - Added schwa

Biofeedback

- Wavesurfer – real-time visual image of speech signal - free downloadable from Source Forge at: https://sourceforge.net/projects/wavesurfer/
  - Voicing contrasts

Biofeedback

- Linear predictive coding (LPC) spectrum (non-CAS) (McAllister Byun & Hitchcock, 2012)
  - Visual representation of the acoustic signal of speech
  - F1 and F2
  - Shown as vertical peaks in a waveform (instead of horizontal bars)
  - Clinician produces model and freezes waveform
  - Save clinician model as template
  - Template outline stays on screen as child produces target and tries to match template
  - Also pre-set targets for different ages, sex, size

Summary Biofeedback

- Uses visual feedback of speech movements – to assist the child in understanding what changes are being requested
  - Electropalatography – tongue to palate movements
  - Ultrasound – tongue movements
  - Spectral biofeedback/linear predictive coding (LPC) spectrum
- May be best for older children
- Can be used along with other approaches

Must-Have Features of CAS Intervention Summary

✓
- Goals are MOVEMENT-based, not sound-based
  - Judge accuracy based not only on consonant accuracy but also on
    - Vowel accuracy
    - Coarticulation between sounds and syllables
    - Prosody

✓
- The principles of motor learning are considered?
  - High amount of practice trials
  - Utilize multi-sensory feedback modalities
  - Address the dichotomy of acquisition factors vs. retention factors
  - Distribution of practice across time, environments, and communication partners

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