Radboud University Nijmegen Medical Centre

Genetic, Neuroimaging, & Motor Control Research in Childhood Apraxia of Speech.ASHA Convention, November 21, 2008

MODELING the DEVELOPMENT of CHILDHOOD APRAXIA OF SPEECH (CAS)

Ben Maassen, Ph.D.

Associate Professor of Cognitive Function and Speech-Language Disorders in Children

Hayo Terband, Jaco Pasman, Jonathan Brumberg, Lian Nijland, Leenke van Haaften, Frank Guenther, Pascal Van Lieshout

Paediatric Neurology
Medical Psychology

Classification of CAS requires

1. Listing of one or more **key diagnostic signs or markers**
- inconsistent errors on consonants and vowels
- lengthened and dirupted coarticulatory transitions
- Inappropriate prosody

2. **Core deficit**
- planning and programming the spatiotemporal properties of movement sequences underlying speech sound production,
- representational-level: segmental and/or suprasegmental units in both input processing and production.

3. **Cause or etiology**
Definitions of CAS have universally ascribed its origin to neurologic deficits, with alternative viewpoints differing with respect to specific neuroanatomic sites and circuits.

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1. Key diagnostic signs or markers

Guyette & Diedrich (1981) argued that there are no ***pathognomonic symptoms*** or ***necessary and sufficient conditions*** for the diagnosis DAS.

Thus, although it is clear that DAS causes severe, developmental speech problems, **STILL** there is:

1. Little agreement on which symptoms/behaviors are important
2. Paucity of data to support claims.

As a result, in clinical practice the disorder is mainly defined by exclusion.
DAS is a 'label in search of a population'.

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1. Key diagnostic signs or markers

As stated in the technical report (ASHA, 2007):

"Review of the research literature indicates that, at present, there is no validated list of diagnostic features of CAS that differentiates this symptom complex from other types of childhood speech sound disorders, including those primarily due to phonological-level delay or neuromuscular disorder (dysarthria)"

Criteria for the diagnosis AOS.

McNeil (2004):

It is the thesis of this argument that it is **not a lack of theory or the inability to select the *correct theory*** from the known alternatives that limits understanding of AOS, although these issues are also challenges.

Neither is it the inability to **construct critical experiments**, nor the inability to **select the appropriate level of description or contrast** with the appropriate comparison group that limits understanding of AOS.

It is, likewise, not the lack of neurologic or anatomic instantiation that limits AOS understanding.

The most important impediment to theoretical and clinical advancement in AOS is, however, the lack of a comprehensive and clear definition that leads to an agreed-upon set of criteria for subject selection.

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2. Core deficit of CAS

- a disorder of phonological encoding, resulting in high frequency of inconsistent substitutions *(Thoonen, 1998)*
- a neurologically based disorder in the ability to program movements for speech volitionally *(Smith et al., 1994)*
- an impairment in the mechanism for motor planning and/or motor programming of speech production *(Maassen, Nijland & van der Meulen, 2001; McNeil & Kent, 1990)*
- an impairment of the precision and consistency of movements underlying speech *(ASLHA, 2007 Position Statement)*

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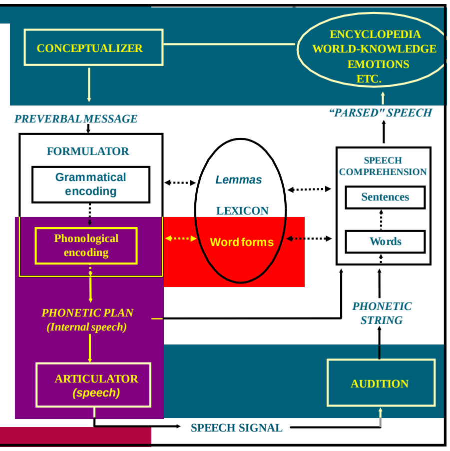
Defective level of processing

1. CAS at level of lexical representation
   → word form representation and retrieval
2. CAS at the level of phonological encoding
3. CAS at the level of motor planning
4. CAS at the level of motor programming
5. CAS at level of motor execution

Level 1
Lexical stress



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Specific symptoms: diagnostic marker

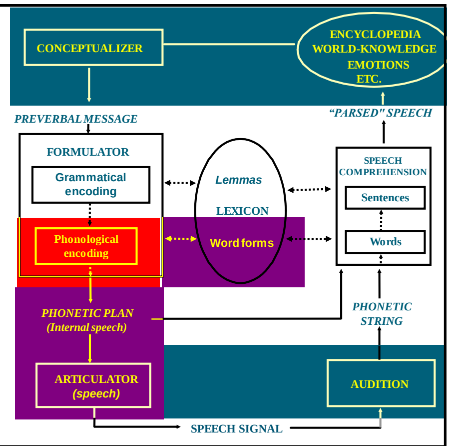
DAS: A subtype marked by inappropriate stress
Shriberg, et al., JSLHR, 1997

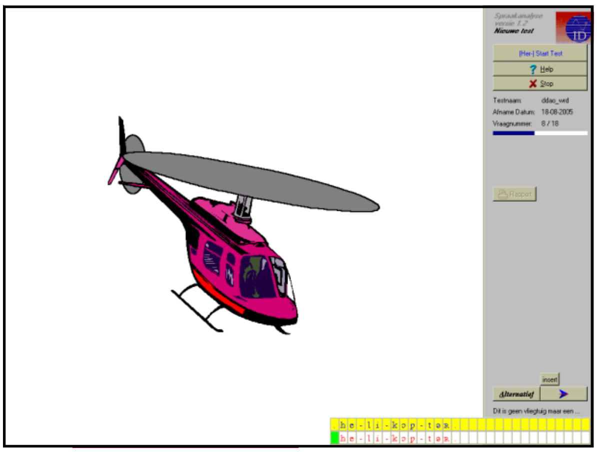
Main result: 52% of 48 eligible samples from 53 children with suspected DAS had inappropriate stress,
compared to **10%** of 71 eligible samples from 73 age-matched children with speech delay of unknown origin.

Developmental evidence suggests that lexcial stress errors are the result of incorrect word forms (rather than incorrect processing).
Velleman, et al., JSLHR, 1999

The lexical stress errors of children in both SD and SD-DAS disorder groups were found to conform to patterns identified in metrical studies of younger normally developing children. Lexical metrical patterns did not differentiate the groups from each other. → **low specificity**

Level 2
Phonological
encoding





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Speech characteristics in children with s-CAS referring to phonological encoding difficulties

- Poor sequencing of sounds
- Low phonemic & phonetic inventory
- Frequent vowel errors
- Substitutions of consonants
- Deviant phonological patterns

Forrest, AJSLP, 2003

- Syllable structure errors
- Anticipations / Perseverations
- Errors in Place-of-Articulation

Thoonen et al., JSHR, 1998

Clinical characteristics of CAS
- criteria for subject selection
- categorical approach

-Poorly or unintelligible speech (also reported by care-givers)
-age-appropriate language comprehension
(discrepancy criterion)
-no evidence of dysarthria
(exclusion of co-morbidity)
-normal hearing
-intellectual abilities within the normal range

Screening items

-runs in families
-deficits in expressive language skills

Specific speech characteristics of CAS

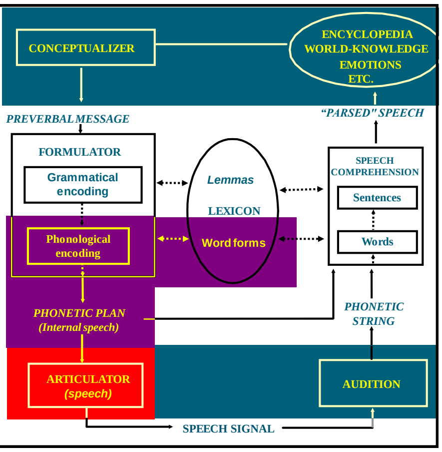
"Difficulties with the transition from a phonological code to speech movements (articulation)"

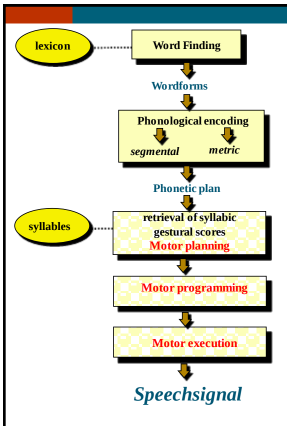
- trial-and-error and struggle, searching or groping behavior
- sequencing difficulties with phonemes and syllables
- syllable structure errors → also complications
- inconsistency of articulation
- deviant coarticulation

History

- resistance to therapy

Level 3, 4, 5
Motor planning
Motor programming
Motor execution





Development of coarticulation

Samples : 'see', 'she', 'Sue', 'shoe'. /si/, /ʃi/, /su/, /ʃu/

Speakers: adults and children age 3 - 7 years

Analysis: - second formant (F2) of vowel and fricative
- spectral moment of fricative

Result children RE adults
- less difference in acoustic spectral moments of fricative
- larger effect of vowel upon fricative F2

Conclusion: **children more coarticulation than adults**
gestures not yet aligned with speech segments.

Nittrouer, Studdert-Kennedy, & McGowan, JSHR, 1989

Speech Material

Syllable boundary: [zus#xVt]

"zus giet"	[z us #xit]	{sister pours}	*"abutting"*
"zus gaat"	[z us #xat]	{sister goes}	
"zus goot"	[z us #xot]	{sister poured}	

Syllable boundary : [ze#sxVt..]

"ze schiet"	[z e#sxit]	{she shoots}	*"cluster"*
"ze schaatsen"	[z e#sxat..]	{they skate}	
"ze schoot"	[z e#sxot]	{she shot}	

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Percentages Syllable Productions

Target	“abutting” s # x			“cluster” # s x		
	Correct	Omission	Pause	Correct	Cluster reduction	Pause
1 RL (5;0)	25.0	41.7	33.3	5.6	83.3	11.1
2 JB (5;1)	94.4	2.8	0	0	97.2	0
14 JP (5;7)	97.2	0	2.8	91.6	0	5.6
17 PM (5;10)	97.2	0	2.8	97.2	2.8	0
20 AA (5;11)	66.7	16.7	11.1	47.2	47.2	5.6
21 KB (5;11)	52.8	33.3	11.1	5.6	88.9	0

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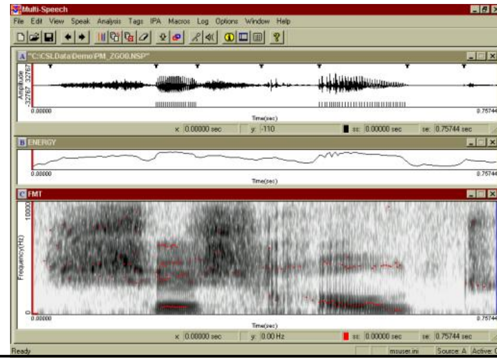
Child with DAS (age 5;10)

“zus goot” [zus#xot] {sister poured}



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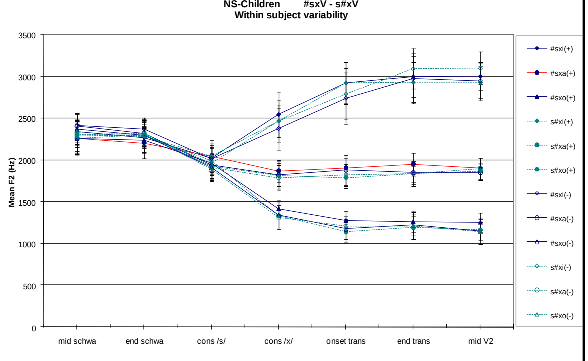

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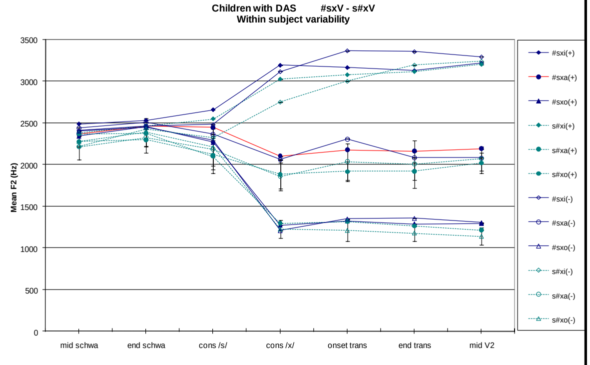

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Results

1. Syllabic structure strongly influences productions
   → effect of phonological encoding
2. Children with CAS show larger vowel (=context) effects.
   → strong coarticulation within and between syllables
   → evidence for <u>motor programming</u> deficit
3. Movement patterns of children with DAS are more variable.
   → a-specific symptom; <u>motor execution</u>?

Nijland, 2003

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Modular Approach … leaves us with …

1. CAS at level of lexical representation
   → word form representation and retrieval
2. CAS at the level of phonological encoding
3. CAS at the level of motor planning
4. CAS at the level of motor programming
5. CAS at level of motor execution

ALTERNATIVE … Network model

Kent (2004) challenged the modularity of motor control processes in general: '..speech, or any motor behavior, is best viewed as a cognitive–motor accomplishment.'

Bishop (1997): cognitive neuropsychology reasoning applied to acquired disorders is based on dissociation.
In developmental disorders associations are the rather than the exception.

Karmiloff-Smith et al. (2003): Although selective deficits in adult patients might justify claims about cognitive modularity, seemingly similar deficits found in children cannot be used to argue that such cognitive modules are prespecified in the infant brain.
→ gradual emergence of the adult modular system

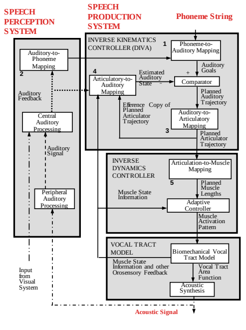
Neural Network model: DIVA

1. Speech-motor behavior is perceptual-motor behavior

   in DIVA: inverse mappings

2. development: acquisition of motor control by trial-and-error

   in DIVA: babbling



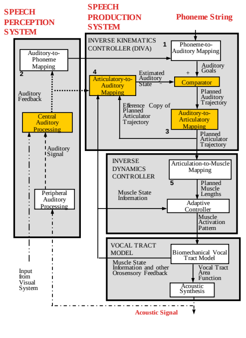
Block diagram of the DIVA Model

Directions Into Velocities of Articulators

PERKELL & GUENTHER
Speech Motor Conference Nijmegen 2001

The synaptic weights are tuned during a babbling phase in which random movements of the speech articulators provide tactile, proprioceptive, and auditory feedback signals that are used to learn the mappings between different neural representations.
Guenther, Ghosh, Tourville 2005

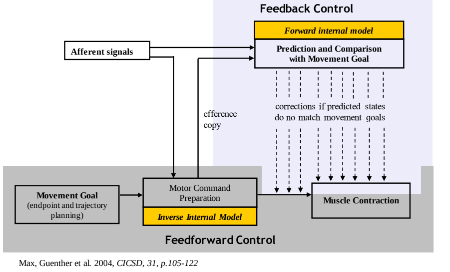
Wolpert & Ghahramani 2001



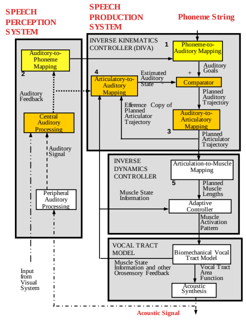
Systemic mapping

PERKELL & GUENTHER
Speech Motor Conference Nijmegen 2001

Systemic mapping



Max, Guenther et al. 2004, *CICSD, 31, p.105-122*



Phoneme-specific mapping

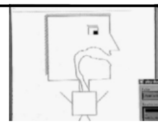
Systemic mapping

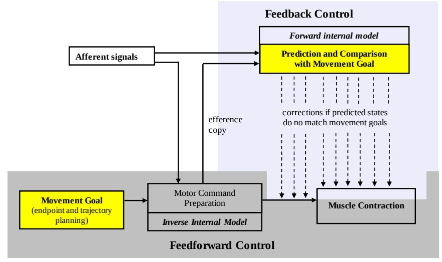
Block diagram of a model of the segmental component of speech motor control and the influence of feedback.

PERKELL & GUENTHER

Speech Motor Conference Nijmegen 2001

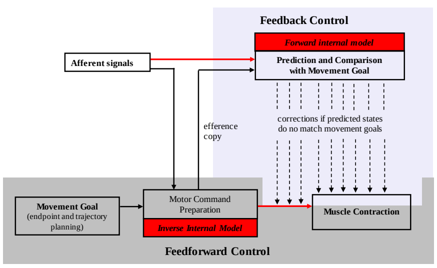
Phoneme-specific mapping





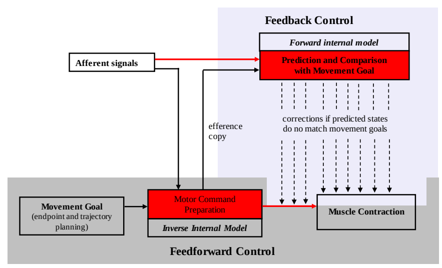
Max, Guenther et al. 2004, *CICSD, 31, p.105-122*

Hypothesis 1. Unstable / Insufficiently developed internal models -> Overreliance on Afferent Feedback



Max, Guenther et al. 2004, *CICSD, 31, p.105-122*

Hypothesis 2. Weak Feedforward control -> Overreliance on Afferent Feedback



Max, Guenther et al. 2004, *CICSD, 31, p.105-122*

Simulation study: Methods

Manipulation of **feedforward/feedback ratio** during imitation learning of new utterances

Systemic mappings are fully acquired.

Symptoms assessed:

- deviant coarticulation
- speech sound distortion
- searching articulation
- increased variability

Utterances: V1 – C – V2 V1, V2 = {a, i, u}

e.g. / a b i / C = b, d, g}

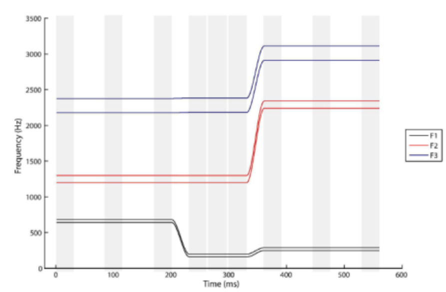


Figure 2. Schematic representation of the speech sound-target for /abi/. The light grey columns indicate the measurement points. At each of these points, the mean formant value was calculated over a 30 ms time window (three measurements with 10 ms time intervals).

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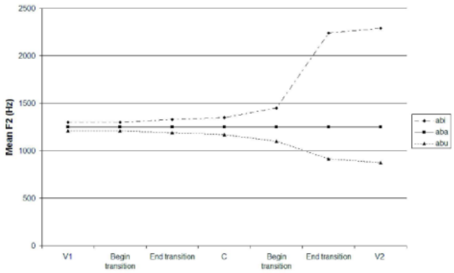

Figure 3. Example of coarticulation: the F2-values of V1 and C differ depending on V2.

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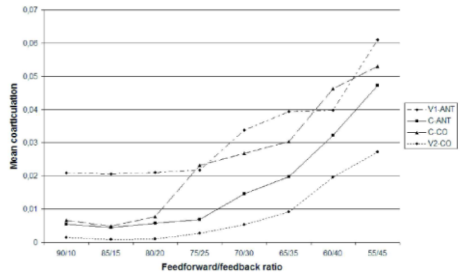

Figure 4. Anticipatory (ANT) and carry-over (CO) coarticulation for V1, C, and V2 in relation to feedforward/feedback ratio.

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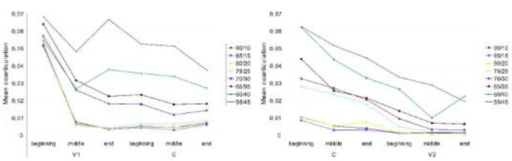

Figure 5. Anticipatory (left) and carry-over (right) coarticulation for different feedforward/feedback ratios.

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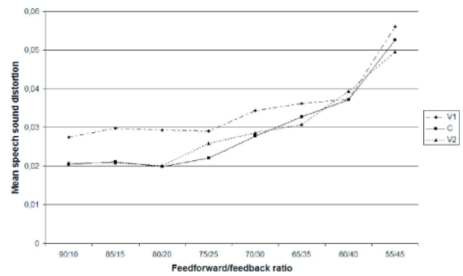

Figure 6. Vowel distortion in relation to feedforward/feedback ratio.

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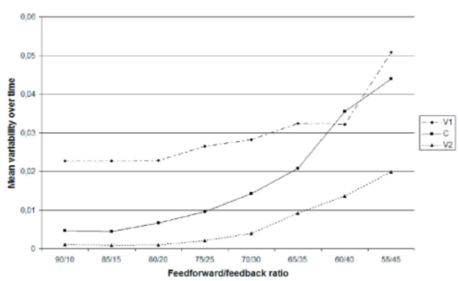

Figure 7. Groping: variability over the course of the production of speech sounds in relation to feedforward/feedback ratio.

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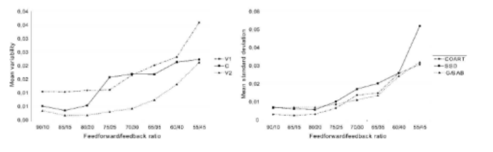

Figure 8. Token-to-token variability: mean variability of mean formant frequencies (left) and mean standard deviation of the coarticulation, speech sound distortion, and groping indices (right) between productions of speech sounds.

Further research

1. Test the specificity of the results by comparisons with other parameter manipulations (e.g. neural noise)
2. Further tracking phonological development and possible deficient word-form representations as the result of deviant perceptual- motor development.
3. Focus not only on specific symptoms of CAS, but also on non-specific speech and other symptoms.
   Secondary features are as vital as the core features in constraining a theory.
   Morton & Frith, 2000, (p. 358)
   Analyze overlap between CAS and phonological disorder at particular developmental stages.

Further research

"The phonetic parameters characterizing early words are also characteristic of prior and contemporaneous babble"
Oller, Wieman, Doyle, & Ross, 1976; Stoel-Gammon & Cooper, 1984; Vihman, Macken, Miller, Simmons, & Miller, 1985

Children with a phonological disorder need more redundant acoustic information to perform a perception task, and produce less precise and less controlled (more ballistic) speech movements in a production task, as compared to age-matched controls and adults.
McCune & Vihman, 2001

Further research

Last but not least ....

... test model predictions with behavioral data.

Some examples

Speech Learning experiment

Task: Learn new syllables like:
/mlVC/, /nlVC/, /mʊVC/ , /mʊVC/

Conditions:
- Articulatory instruction without auditory target
- Auditory training, then articulatory training

Prediction:
- Due to poor systemic mapping, children with CAS profit less from auditory training than children with SSD of a different origin.

Thank you for your attention