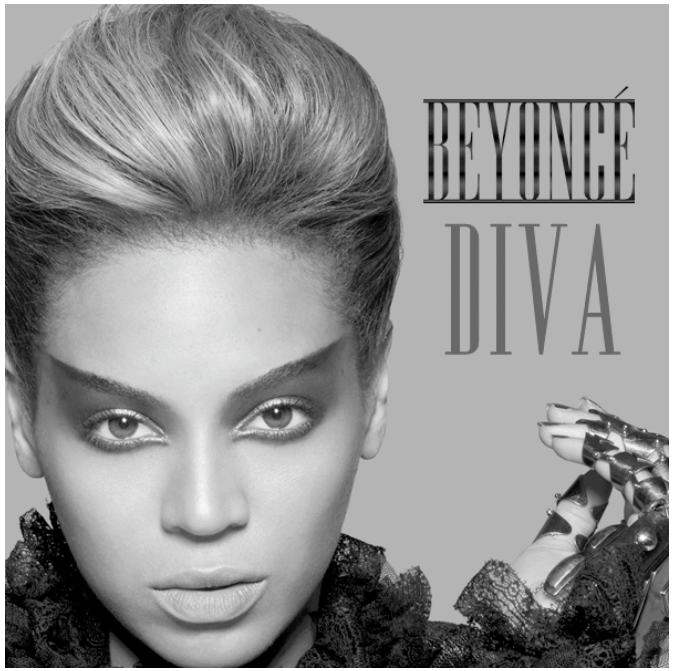
What has DIVA got to say about FAS?

Nicola Bessell

Department of Speech and Hearing Sciences, University College Cork, Ireland

What is DIVA?



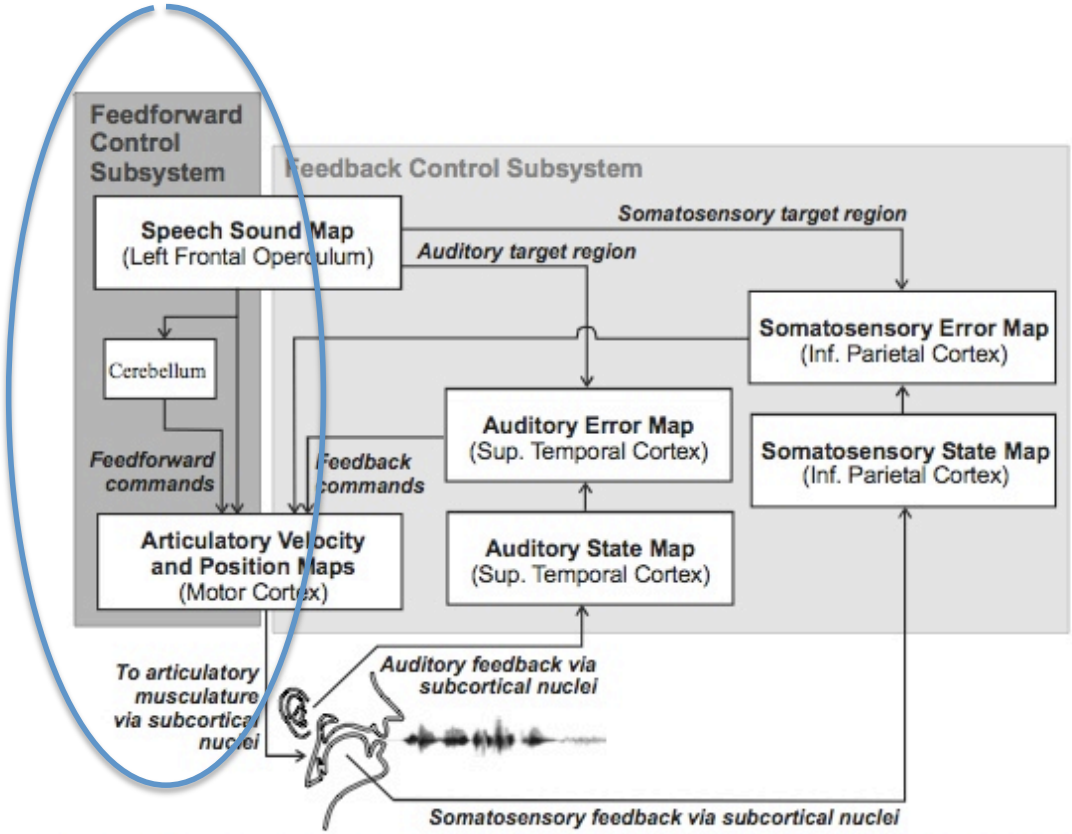


Figure 1. Schematic of the DIVA model of speech acquisition and production. Projections to and from the cerebellum are simplified for clarity.

Directions into Velocities of Articulators: Guenther 2006, Golfinopolous et al., 2010.

What is FAS?

Foreign Accent Syndrome: acquired neurogenic disorder which results in speech that is heard with a 'foreign accent'.

pseudo accent

Lecours, Lhermitte, & Bryans, 1983

unlearned foreign accent

Graff-Radford, Cooper, Colsher,
& Damasio, 1986

changed or altered accent syndrome

Brain bug changes woman's accent

A woman from Staffordshire who temporarily lost the ability to speak has begun talking again with a distinctive European accent.

Kath Lockett, 47, was struck down with a rare brain condition called severe cerebral vasculitis in 2004 and in March this year was unable to speak.

Foreign Accent Syndrome was first identified during World War II

news.bbc.co.uk/2/hi/uk_news/england/staffordshire/5165588.stm

Foreign Accent Syndrome
on "My Strange Brain" Part 1
/www.youtube.com/watch?v=f1rC43dvbws

A therapist's experience

I received a communication referral to see a young woman who presented with dysarthria-or at least this is how her speech initially presented. However, something was not quite right about her speech-she sounded like she was from Germany. This was very strange as her English, grammatically and syntactically, was intact. The ward staff could not believe she had not grown up in Germany or that she had never even visited the country. She had no history of mental illness....I discussed this with my team and we decided FAS was the only explanation-diagnosis by default.

Deborah Johnston, SLT Ulster Hospital Dundonald. *RCSLT Bulletin*, January 2011.

Classic features of FAS from this case

- can be attended by other complicating factors (dysarthria here, but also aphasia, apraxia)
- syntax and other grammatical features of native language 'intact'
- person sounds as if from a country whose language they have never spoken and may never have visited
- diagnosis is differential or by exclusion

Dysarthria

Muscle weakness resulting in articulatory problems:

- slurring
- speech volume and rate can be affected.

Unlike FAS in that effects of dysarthria are:

- constant under all speech conditions
- commonly produces phonetic qualities/ distortions not found in the world's languages.

Aphasia

Non-fluent/Broca's aphasia sometimes confused with FAS.

- problems with word recall: anomia
- short utterances
- halting effortful speech
- monotone intonation
- restricted F0 range
- consonant mis-productions predominate
- V substitutions occasional

There are cases of 'pure' FAS, about 30%, with no co-morbidities.

Apraxia

Viewed as a problem with motor planning/programming rather than muscle weakness (cf. dysarthria).

- disturbs smooth articulatory movements
  - lengthening of words and vowels
  - a slowed rate of speaking that affects segments, transitions and pauses
  - an alteration of stress and rhythmic patterns
  - segmental and voicing errors and less coarticulation

Scott et al. (2006)

Problems...

- Apraxia is difficult to differentiate from Broca's aphasia or 'motor' aphasia (left anterior lesions) and even dysarthria, especially ataxic dysarthria.

- If apraxia is implicated it is of a very mild sort and the conflation of FAS and apraxia is not supported by all researchers. Difference of degree or kind?

Varley and Whitehead (2006); Kanjee et al. (2010); Moen (2006); Miller et al. (2006).

General characteristics of FAS

- speech sounds 'foreign' rather than 'pathological' or 'disordered' as is common with dysarthria, aphasia, apraxia
  - 68% co-occur with aphasia, apraxia, dysarthria. (Blumstein and Kurowski 2006 citing Aronson 1990).

- occurs after some kind of cerebro-vascular accident, brain injury: damage to central nervous system

- the accent is unlike the patient's speech prior to insult

Foreign Accent Syndrome

- there is frequently no evidence at all in patient's background as a speaker of another language (or of language of perceived accent).
- listeners vary on 'accent' identified, but never an accent that is not 'accessible' in some way to the listener
- cluster of features, but varies with patient
- get variability rather than consistent errors

Foreign Accent Syndrome

When you look at the data closely FAS shows segmental and/or prosodic changes

- phonetic and phonological contrasts disturbed on vowels and consonants (place, manner, voicing)
- dysprosody (Monrad-Krohn)
  - intonation/pitch/stress misplacement
  - rhythmic disturbances

FAS in speakers of English

- syllable rather than stress timing
- epenthetic vowels (disrupt syllable structure)
- rising F0 contours where not expected
- monotonic prosody
- F0 not disrupted
- changes of place, manner and voicing in C's
- altered V space
- increased variability in vowels

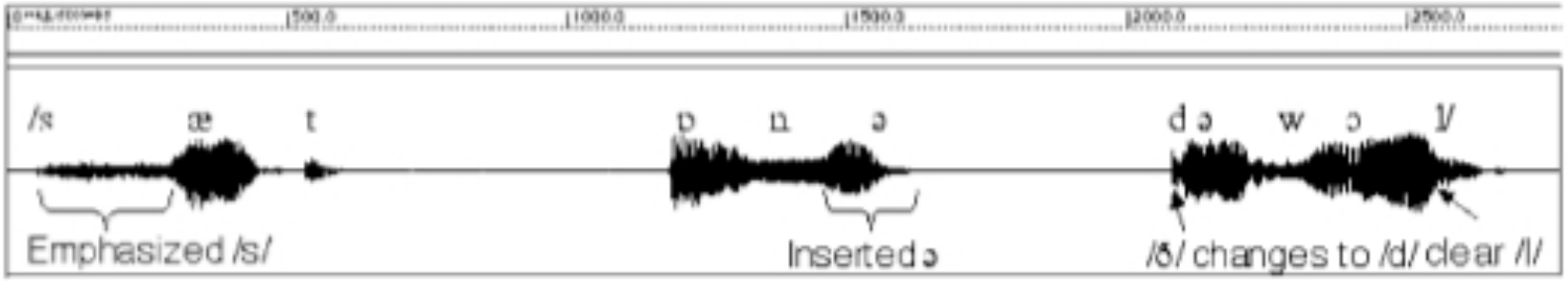


Fig. 2. Oscillogram of EM saying 'sat on the wall' as part of the poem 'Humpty Dumpty'. Typical speech errors are annotated: note also the long gap between words.

[s] duration increased

inappropriate epenthetic schwa

fortition of fricative to stop

loss of velarisation on final- [l].

Scott et al. 2006. Foreign accent syndrome, speech rhythm and the functional neuronatomy of speech production. *Journal of Neurolinguistics 19, 370-384.*

Etiology: might be a way of differentiating

- damage to speech output motor system in language dominant hemisphere affecting the primary motor cortex and either its cortico-cortical connections or its cortico-subcortical projections (Blumstein & Kurowski, 2006).

- a few cases of psychogenic origin otherwise some kind of cerebro-vascular accident

FAS lesion sites

- anterior left-hemisphere predominantly
- prerolandic motor cortex (BA 4), frontal motor association cortex (BA 6 or 44) , or striatum.

These are lesion areas typically implicated in Broca's aphasia and 50% of FAS are aphasic, but FAS not typical of aphasic speech in general.

FAS lesions usually smaller than those associated with aphasias.

FAS relevant sites...

- basal ganglia regions and adjacent insula cortex (implicated in apraxia) Scott et al. 2006
- Right hemisphere?
- cerebellum (Marien et al. 2006)

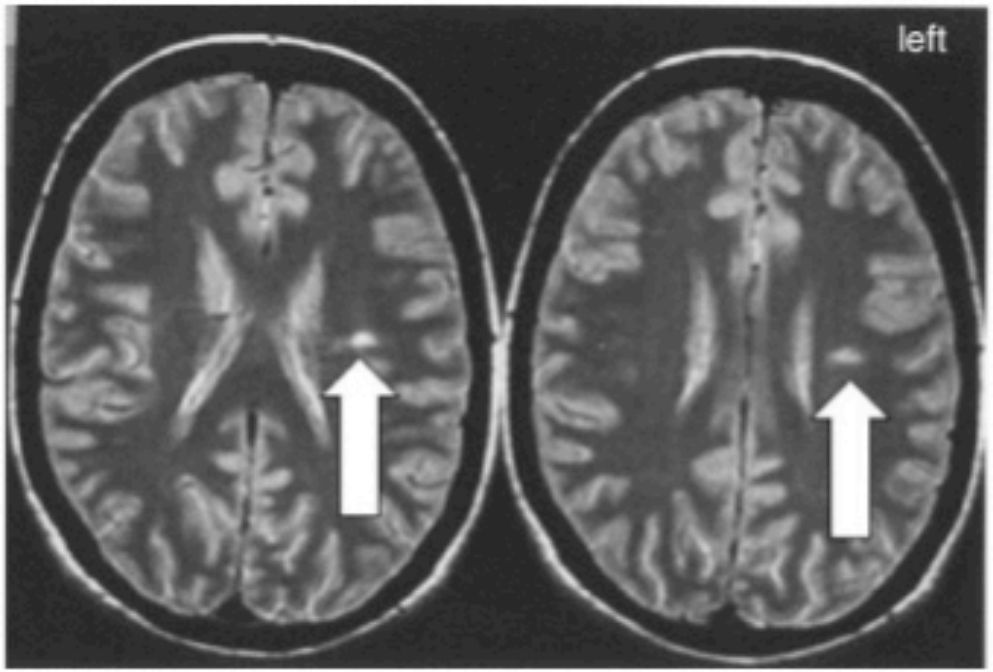


Fig. 1. Two axial slices of magnetic resonance imaging scans of EW, showing the location of her lesion in the white matter, medial and dorsal to the anterior insula, lying ventral to the precentral gyrus (primary motor cortex). The lesion location is marked with arrows.

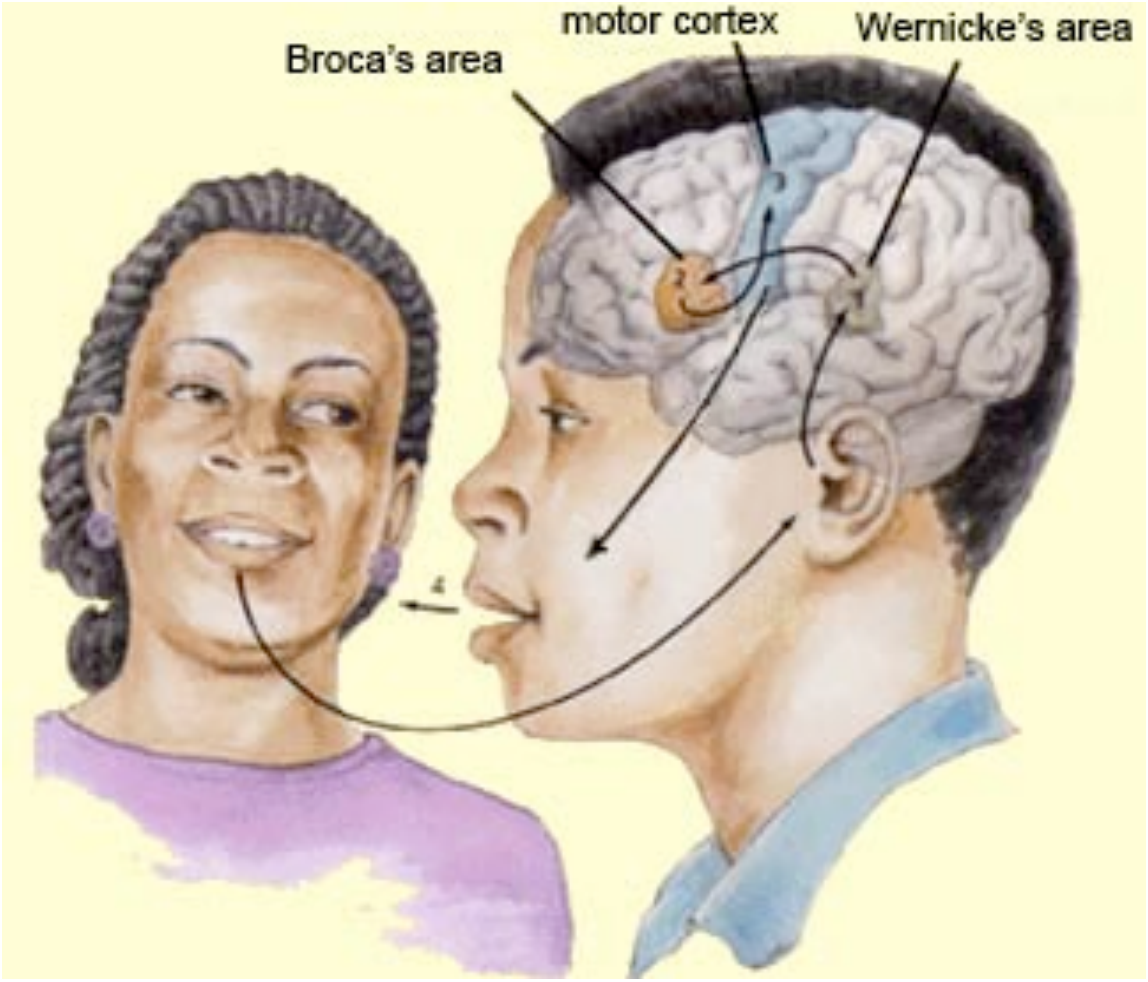
Suggested mechanisms

- supralaryngeal VOT setting is altered
  - hypertonic/tense vocal tract setting
  - paretic/lax vocal tract setting
- motor control/timing of articulators is disrupted
  - prosodic/segmental alignment disturbed
  - segmental voicing errors
  - stress variation

Suggested underlying mechanisms

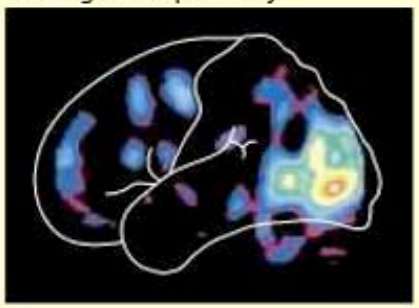
- breakdown of processing of speech production in the brain
  - 'foreign accent syndrome is associated with a disconnection of the planning of articulation from motor control...' (Scott et al. 2006:370).

Locationist models with serial processing: Geschwind-Wernicke 1960's/70's

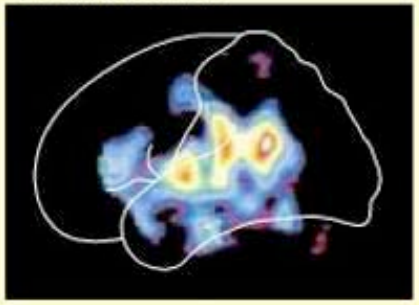


thebrain.mcgill.ca/flash/d/d_10/d_10_cr/d_10_cr_lan/d_10_cr_lan.html

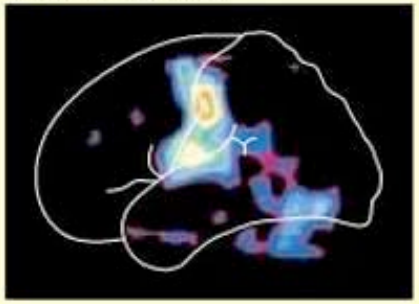
Seeing words passively



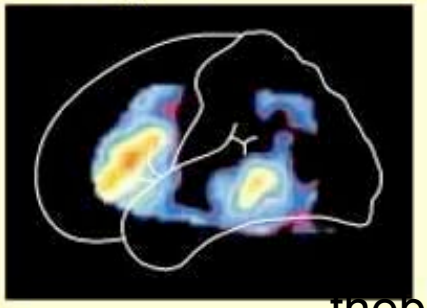
Listening to words



Pronouncing words



Generating words



... understanding or producing a spoken or written word can require the simultaneous contribution of several modalities (auditory, visual, somatosensory, and motor). Hence the interconnected neurons in the assembly responsible for this task may be distributed across the various cortexes dedicated to these modalities.

thebrain.mcgill.ca/flash/a/a_10/a_10_cr/a_10_cr_lan/a_10_cr_lan.html#2

What is DIVA?

Directions into Velocities of Articulators

A neurocomputational model of speech production which incorporates auditory and somatosensory feedback in a distributed neural network. The components are anatomically situated based on fMRI data from language acquisition and production so DIVA relates speech processing activity with anatomical location. DIVA 'learns' to control a vocal tract model, specifications from this are input to a speech synthesizer....

DIVA (Guenther 2006)

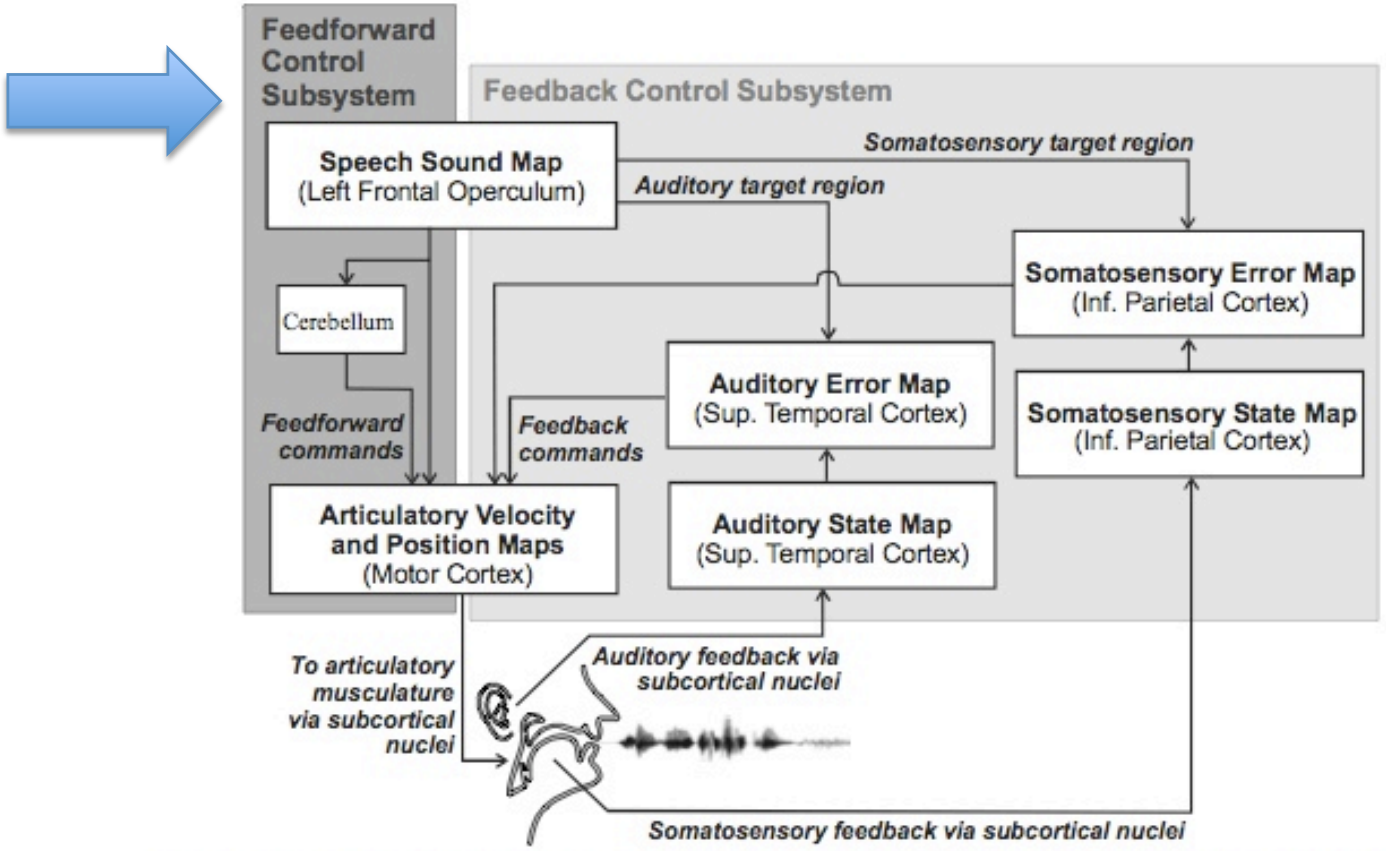
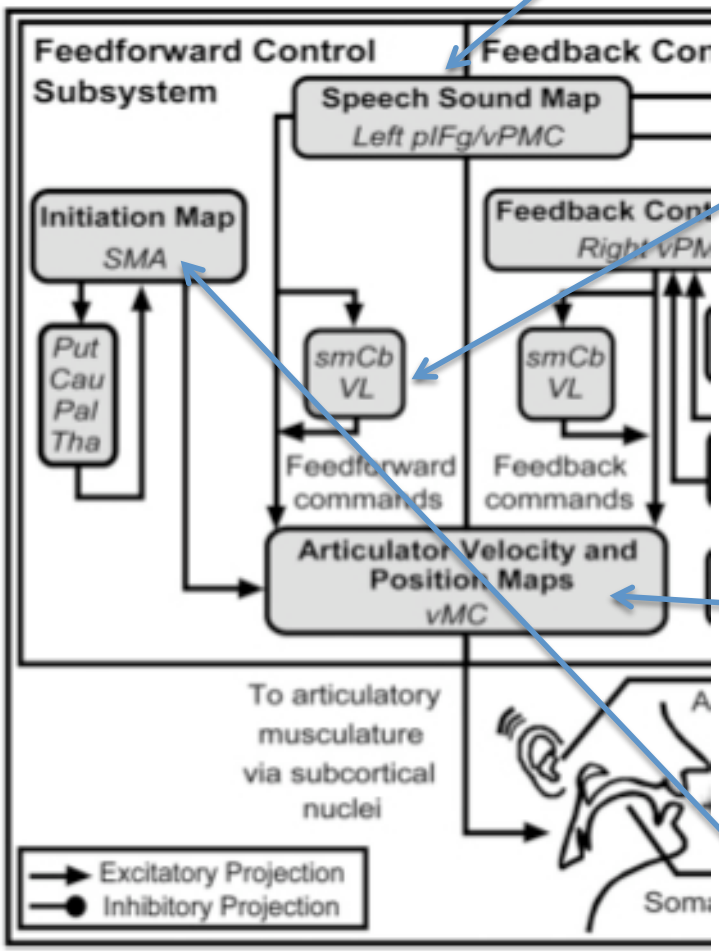


Figure 1. Schematic of the DIVA model of speech acquisition and production. Projections to and from the cerebellum are simplified for clarity.



Golfinopolous et al., 2010

S S Map cells encode the lexical representation of a sound as auditory and articulatory information. Mirror cells. Activated in production and perception. Left posterior frontal gyrus/ventral premotor cortex.

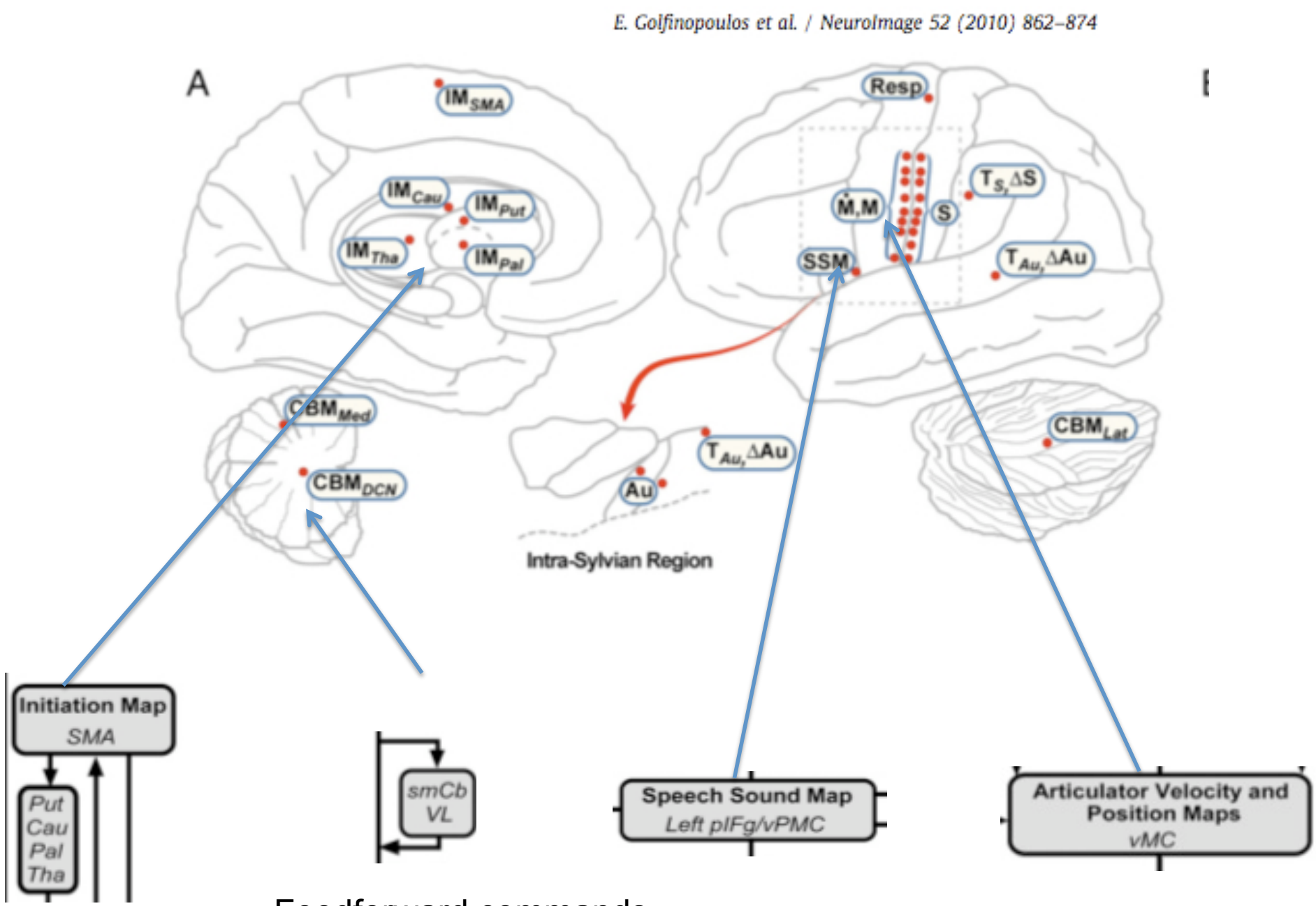
Feedforward commands from Speech Sound Map are in the form of a motor program/gestural score sent via the superior medial cerebellum/ventral lateral nucleus of the thalamus.

FFCs activate cells in the Articulator Velocity and Position maps, located in ventral motor cortex.

Initiation Map releases motor commands for the production of sounds now in the AVPM. Timing of initiation commands based on reciprocal connection with basal ganglia, including putamen, caudate, pallidum, thalamus.

LH, medial region

LH, lateral region



Feedforward commands

Articulatory Velocity and Position Maps

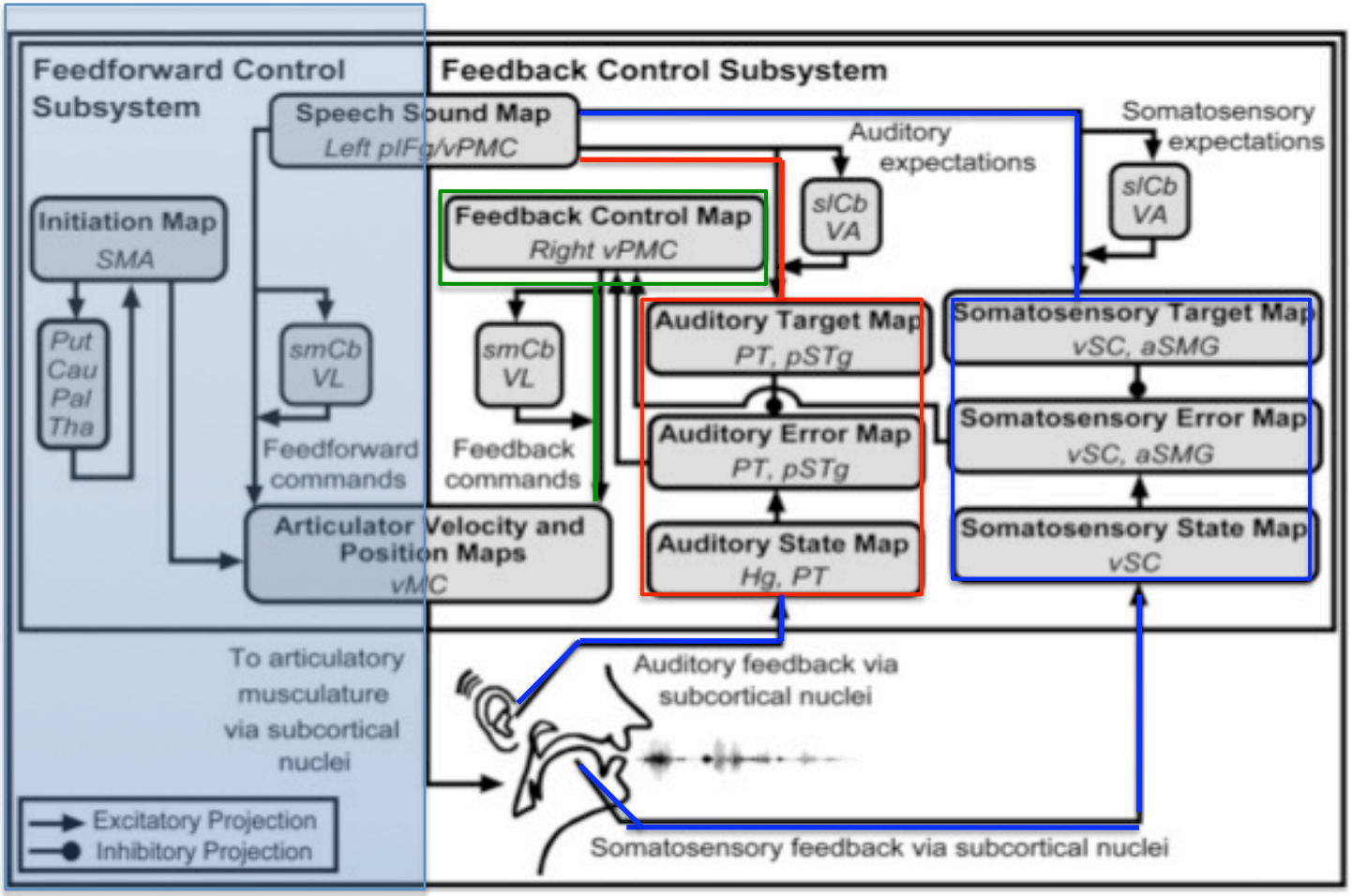
8 pairs cells, 8 degrees of freedom of vocal tract

jaw height
tongue shape
tongue tip
tongue body shape
larynx height
upper lip height
lower lip height
lip protrusion

Feedback system...briefly

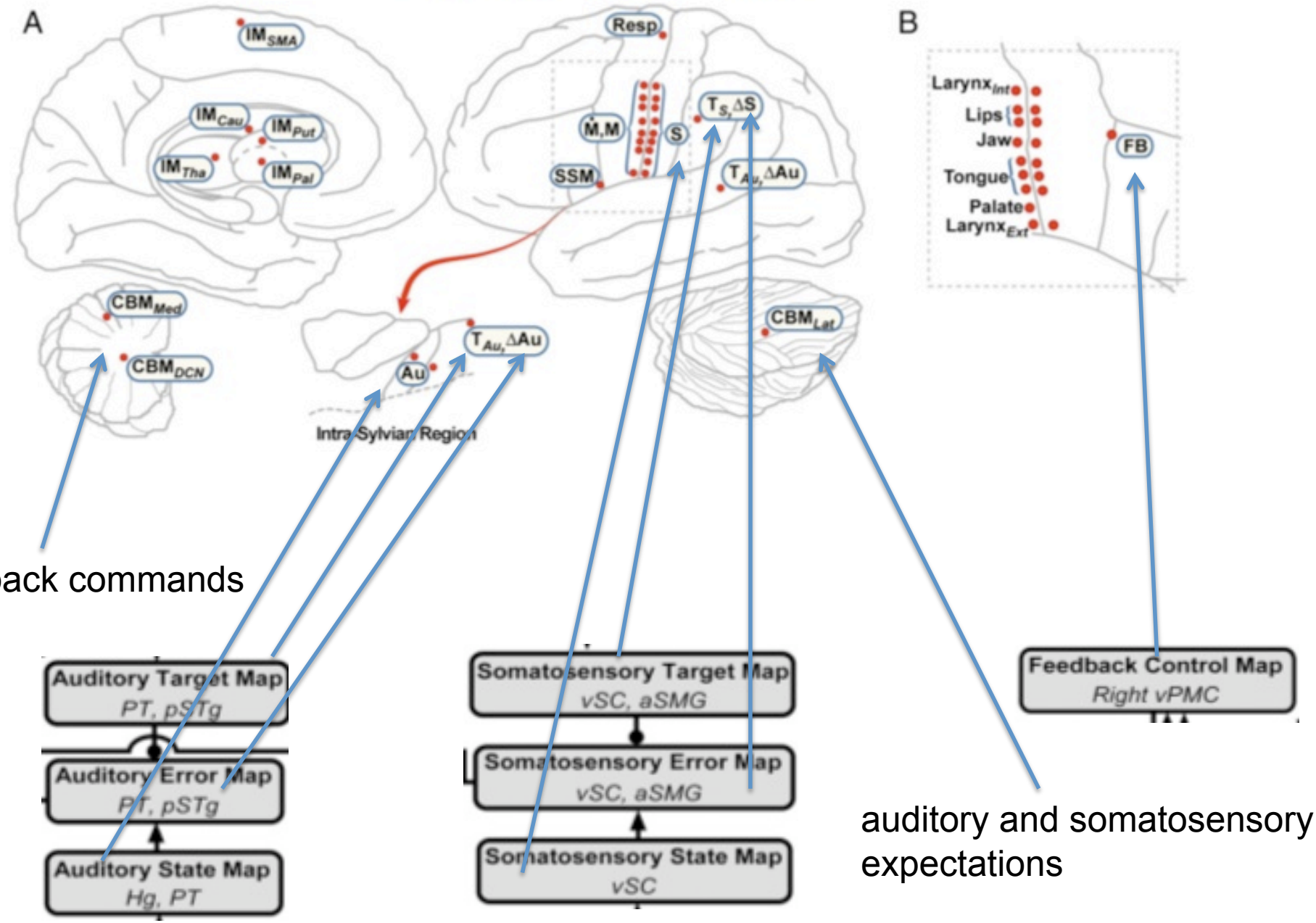
- monitors auditory (F1-F3) and somatosensory accuracy as sound is produced

- compares auditory and somatosensory feedback with learned target ranges and feeds any corrections back into the Articulator Velocity Position maps



aSMg = anterior supramarginal gyrus; Cau = caudate; Pal = pallidum;
Hg = Heschl's gyrus; pIFg = posterior inferior frontal gyrus;
pSTg = posterior superior temporal gyrus; PT = planum temporale;
Put = Putamen; slCB = superior lateral cerebellum;
smCB = superior medial cerebellum; SMA = supplementary motor area; Tha = thalamus;
VA = ventral anterior nucleus of the cerebellum;VL = ventral lateral nucleus of the thalamus;
vMC = ventral motor cortex; vPMC = ventral premotor cortex;
vSC = ventral somatosensory cortex.

E. Golfinopoulos et al. / NeuroImage 52 (2010) 862–874



Learning to speak in DIVA

- model learns mapping between articulator movement and sensory (auditory and somatosensory) feedback (babbling stage)
- learns sensory targets and corresponding articulation for frequently occurring sounds or sequences (imitation stage)
- builds speech sound maps over time, with auditory and somatosensory feedback
- once targets have stabilised DIVA can rely on feedforward route only

Overview

The production of a speech sound in the DIVA model starts with activation of a speech sound map (set of neurons).

This results in motor commands to motor cortex via

- a feedforward control subsystem (more direct)
- a feedback control subsystem
  - an auditory feedback control subsystem
  - a somatosensory feedback control subsystem.

How is DIVA different?

- all of the model's components have been associated with specific anatomical locations in the brain based on neuroimaging and other techniques
- simulated fMRI data showing areas of cell activation can be tested against real data
- acoustic results of 'changes/damage' to model can be assessed and compared to known disorders

Childhood apraxia of speech

- inconsistent errors of Cs and Vs
  - diphthong reduction
  - tensing, laxing
  - derhotacisation
  - C omissions

- disrupted coarticulatory transitions
- nonphonemic productions very difficult to transcribe
- groping

Childhood apraxia of speech

- inappropriate prosody
- large within subject variability
- low repetition rates in diadochokinesis
- assessed as a problem transforming phonological code into motor speech commands.

DIVA simulation of CAS
(Terband et al. 2009)

Hypothesis:

feedforward control damaged

therefore more reliance on feedback

Simulation:

vary ratio between feedforward and feedback contribution from 90:10 to 55:45 in 5% steps

VCV sequences V= [i,a,u] C=[b,d,g]

DIVA simulation of CAS

Evaluate acoustic output for

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

  – No mechanism for evaluating suprasegmentals/prosody, or segmental omissions, sustitutions, reorderings.

As feedforward decreased...

- increased coarticulation, particularly carry over
- increased speech sound distortion
- increased searching
- increased variability

What provokes increased carryover coarticulation?

Coarticulation is partly a result of biomechanical constraints on articulators of different size, mass, agility.

DIVA has no representation of this.

DIVA gets the coarticulation effect by DELAY in transmission of control loop information.

DIVA simulation of CAS

I. DIVA model parameters

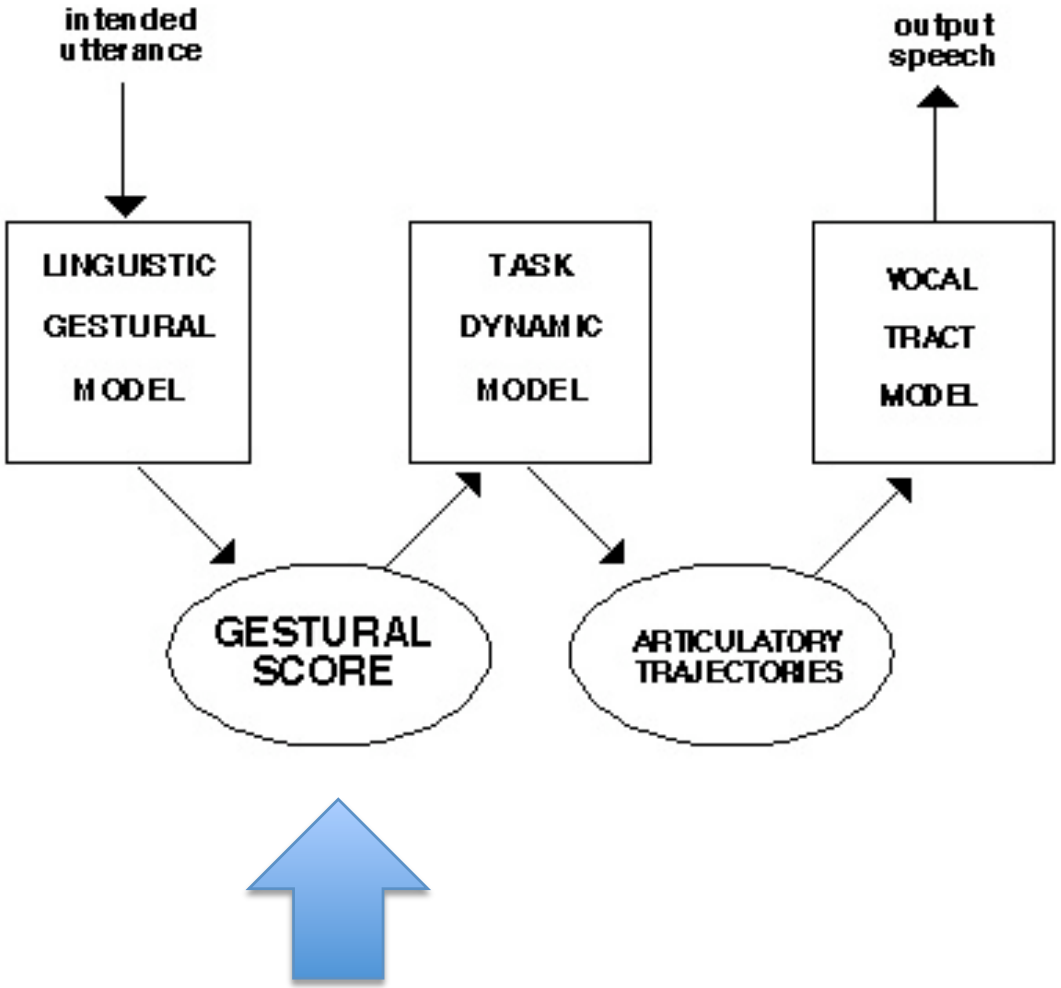
Name	Default Value	Description
α_{ff}	0.9	Contribution of feedforward command to total command; feedforward gain
α_{fb}	0.1	Contribution of the feedback command; feedback gain
τ_{MAr}	5 ms	Transmission delay from motor cortex cell activity to physical movement of articulators
τ_{ArS}	10 ms	Transmission delay from movement of articulators to feedback signals in somatosensory cortex
τ_{ArAu}	25 ms	Transmission delay from movement of articulators to feedback signals in auditory cortex
τ_{PM}	5 ms	Transmission delay from premotor (speech sound map) to motor cortex
τ_{PS}	20 ms	Transmission delay from premotor to somatosensory cortex
τ_{PAu}	35 ms	Transmission delay from premotor to auditory cortex
τ_{SM}	5 ms	Transmission delay from somatosensory to motor cortex
τ_{AuM}	5 ms	Transmission delay from auditory to motor cortex

Terband et al., 2009.

One reason why

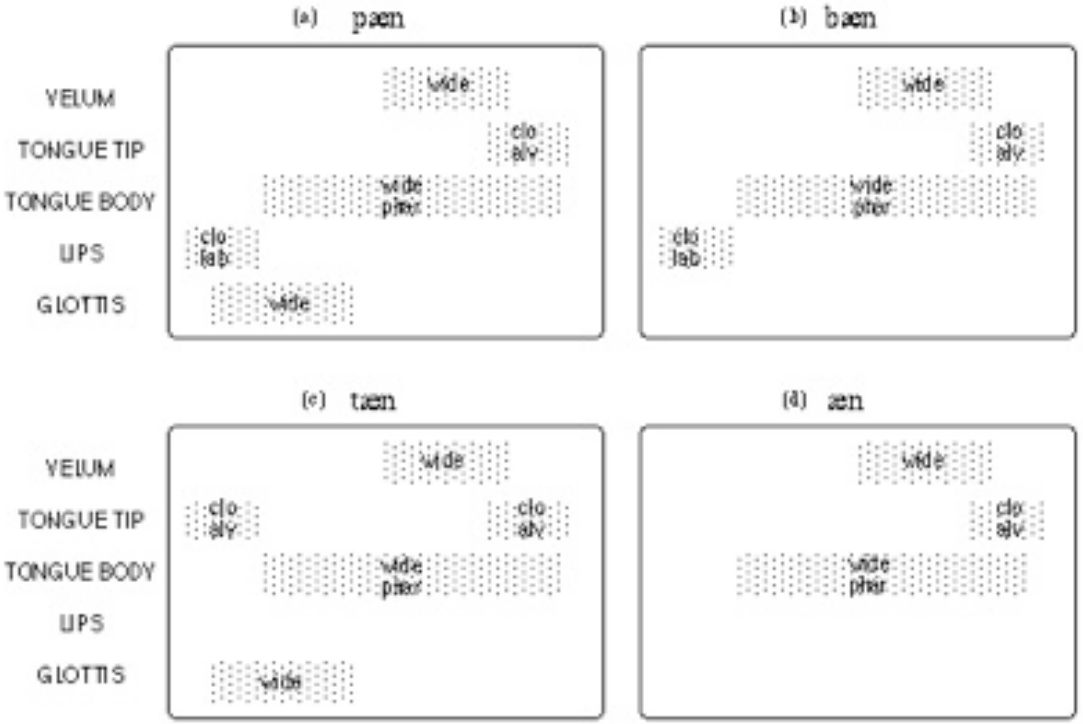
- presence of neural 'noise' degrades the feedforward signal so that this route contributes less to speech production

Gestural phonology: Browman and Goldstein (1992)

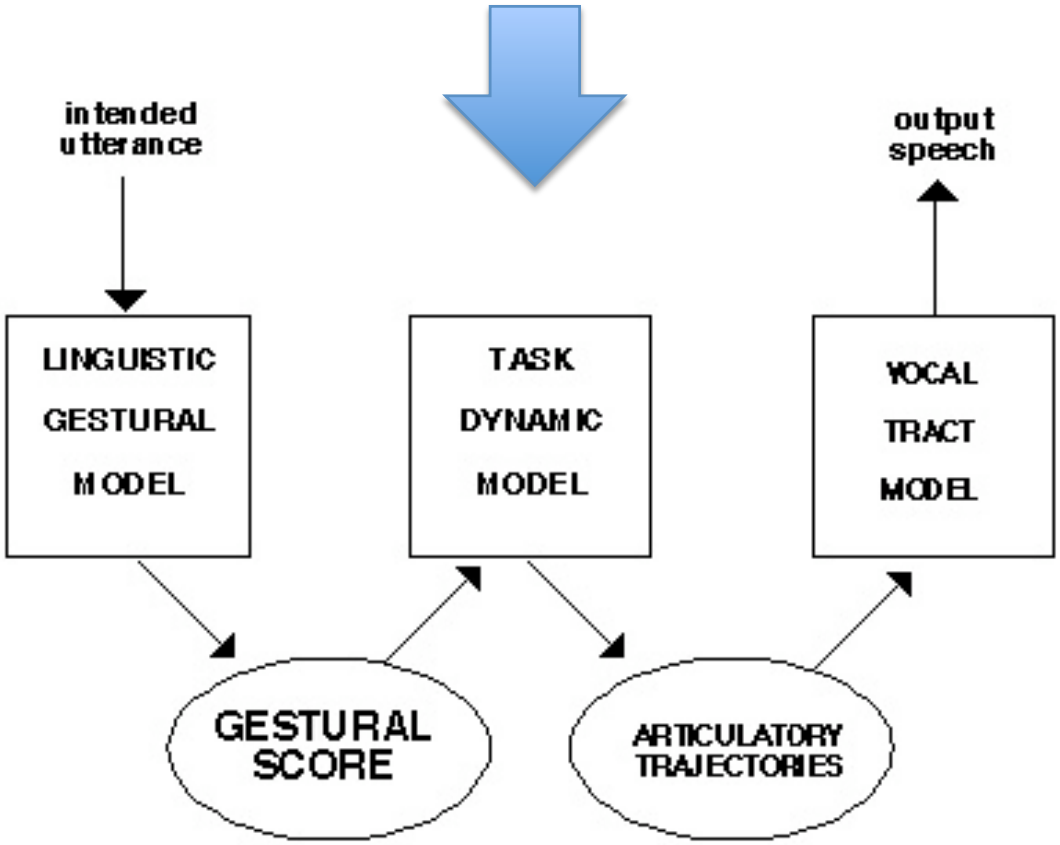


Gestural scores

www.haskins.yale.edu/research/gestural.html

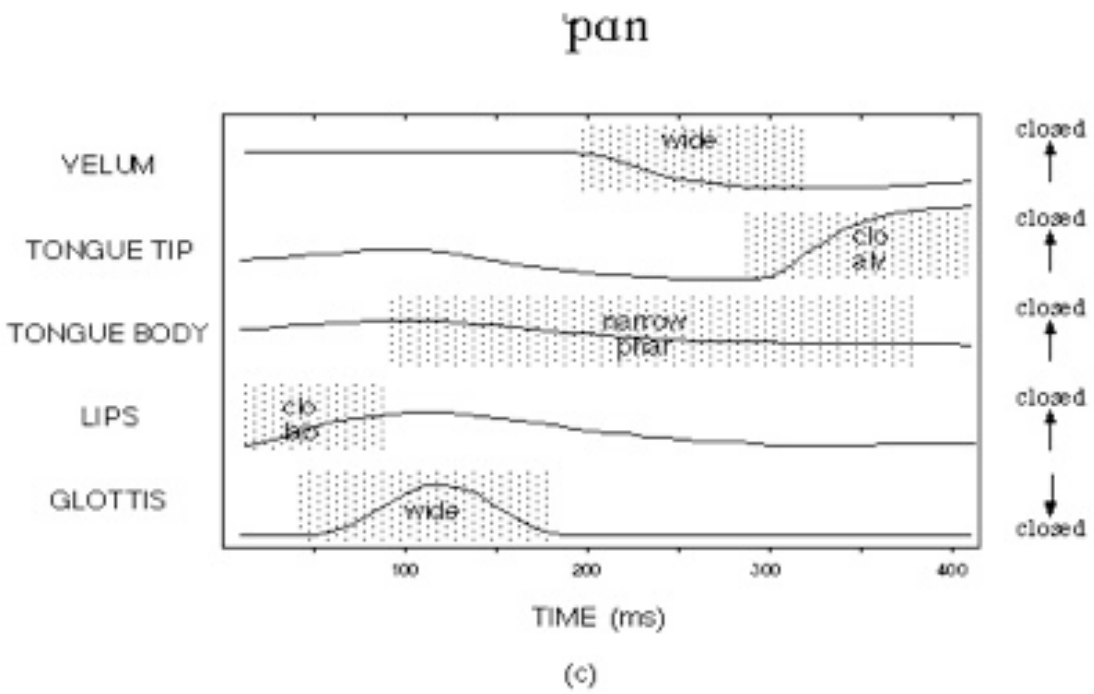


Gestural phonology



Gestural score with trajectories

www.haskins.yale.edu/research/gestural.html



Gestural phonology and FAS

So, loss of information about overlap of gestures in original score will result in variable realisation of timing/phasing. Could get this effect due to damage to SSM or feedforward pathways from it. Damage to SSM itself should result in consistent errors. Damage to pathways predicts variable errors.

Gestural phonology and FAS

- FAS
  - degrading of gestural score representation (SSM)
  - problems with transmission of gestural score information ('noise' in neuronal pathways)
  - problems with task dynamics which specify interaction of articulators (DIVA doesn't have this)
  - stiffness settings of articulators...if this changes the output will change (DIVA has no analogue of this)

Varley and Whiteside et al., 2006.

In a disrupted system such as that which occurs in AOS, because verbo-motor patterns are either difficult to access or disorganised, the speech production mechanism has to rely on an 'indirect' phonetic encoding route, which involves more on-line computation and therefore a greater cognitive load. This would be the feedback route in DIVA. In other words, increased reliance on feedback.

Suggestions...

Simulate cases

- of pure FAS
- with most detailed information on lesion site
- most detailed description of post-injury speech characteristics

Requires pre-injury speech data!

Can access DIVA simulation code.

- a lot will depend on the quality of the DIVA output
- at the moment it is limited in size of output (learns only single units)
- no prosodic information

References

- Blumstein, S. & Kurowski, K. (2006). The foreign accent syndrome: A perspective. *Journal of Neurolinguistics 19*, 346-355.
- Bohland, J.W. & Guenther, F.H. (2006). An fMRI investigation of syllable sequence production. *NeuroImage, 32* (2), 821-841.
- Browman, C. & Goldstein, L. 1992. Articulatory phonology: an overview. *Phonetica 49*, 155-180.
- Golfinopolous, E.,Tourville, J.A., & Guenther, F. H. 2010. The integration of large-scale neural network modeling and function brain imaging in speech motor control. *Neuroimage, 52*, 862-874.
- Graff-Radford, N. R., Cooper, W. E., Colsher, P. L., & Damasio, A. R. 1986. An unlearned foreign 'accent' in a patient with aphasia. *Brain and Language, 28*, 86– 94**.**
- Guenther, F. (2006). Cortical interactions underlying the production of speech sounds. *Journal of Communication Disorders, 39*, 350-365.
- Hickock, G., Houde, J. & Rong, F. 2011. Sensorimotor integration in speech processing: computational basis and neural organization. *Neuron, 69*, 407-422.
- Kanjee, R., Watter, S., Savigney, A. & Humphries, K. (2010). A case of foreign accent syndrome: Acoustic analyses and an empirical test of accent perception. *Journal of Neurolinguistics,* 23, 580–598.
- Kurowski, K. M., Blumstein, S. E., & Alexander, M. (1996). The foreign accent syndrome: A reconsideration. *Brain and Language*, 54, 1–25.

References

- Lecours, A. R., Lhermitte, F., & Bryans, B. 1983. *Aphasiology.* London: Balliere Tindall.
- Mariën, P., Verhoeven, J., Engelborghs, S., Rooker, S., Pickut, B., & De Deyn, P. P. (2006). A role for the cerebellum in motor speech planning: evidence from foreign accent syndrome. *Clinical Neurology and Neurosurgery*, 108, 518–522.
- Miller, N., Lowit, A., & O'Sullivan, H. (2006). What makes acquired foreign accent syndrome foreign? *Journal of Neurolinguistics,* 19, 385-409.
- Moen, I. (2006). Analysis of a case of the foreign accent syndrome in terms of the framework of gestural phonology. *Journal of Neurolinguistics,* 19, 410-423.
- Scott, S., Clegg, F., Rudge, P., & Burgess, P. 2006. Foreign accent syndrome, speech rhythm and the functional neuronatomy of speech production. *Journal of Neurolingusitics, 19,* 370-384.
- Terband, H., Maassen, B., Guenther, F., & Brumberg, J. 2009. Computational neural modelling of speech motor control in childhood apraxia of speech (CAS). *Journal of Speech and Language Hearing Research, 52*, 1595-1609.
- Varley, R.,Whiteside, S., Hammill, C., & Cooper, K. (2006). Phases in speech encoding and foreign accent syndrome. *Journal of Neurolinguistics,* 19, 356–369.