Brain and Speech
from localisations to networks

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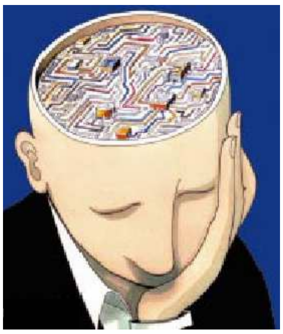
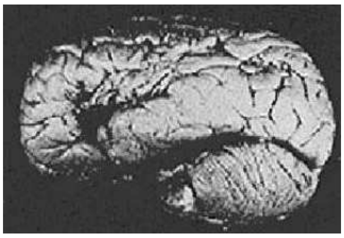


Brain localisations: early descriptions

1848
John Harlow (Phineas Gage)
“ the foundation for the understanding of the neural basis of language and were pursued actively ”



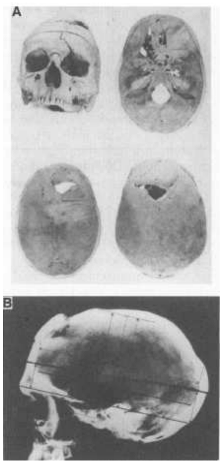
1861
Paul Broca
Anterior inferior frontal gyrus
Speech production

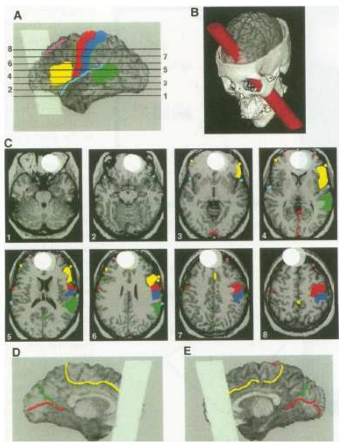
1874
Carl Wernicke
Posterior superior temporal gyrus
Speech comprehension

The Return of Phineas Gage: Clues About the Brain from the Skull of a Famous Patient

Hanna Damasio, Thomas Grabowski, Randall Frank,
Albert M. Galaburda, Antonio R. Damasio*

SCIENCE • VOL. 264 • 20 MAY 1994





Brain localisations: Brodmann's contribution

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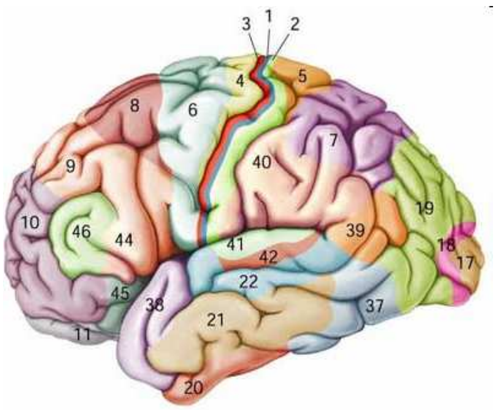
1874

Korbinian Brodmann
Correlation with functions
Area delineations



1 FUNCTION ↔ 1 AREA

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2010, Aix-en-Provence, France

Brain functions: Penfield's contribution

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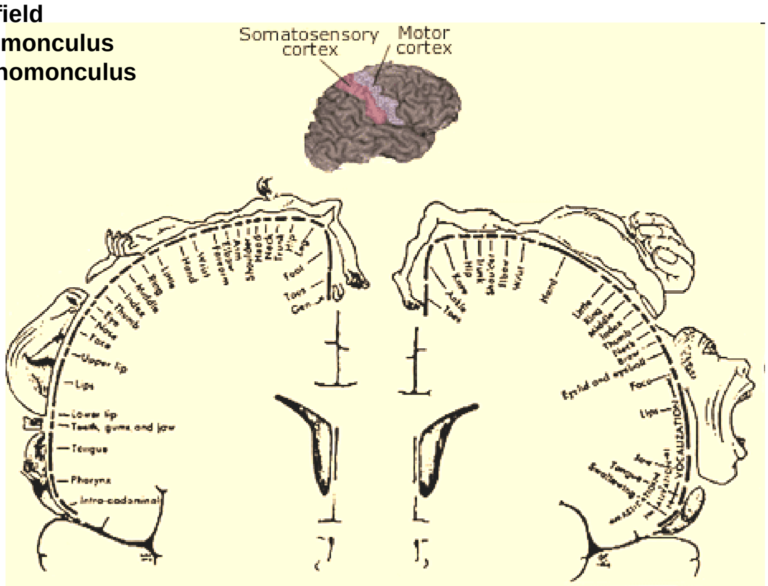
1952

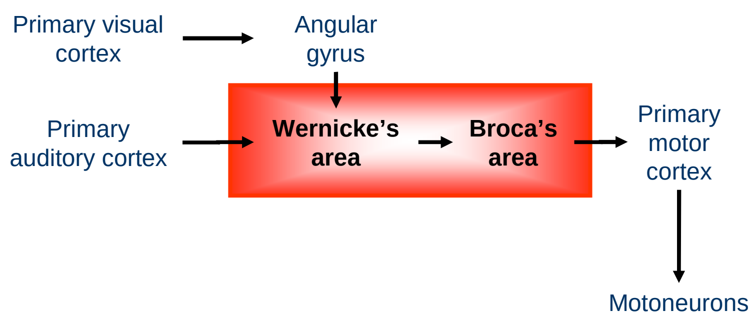
Wilder Penfield
Sensory homonculus
and motor homonculus



Geschwind-Wernicke connexionist model for speech production (1960-1970)

Bipolar, based on the two epicentres represented by Broca's and Wernicke's areas
Areas are involved within a temporal activation cascade

1 function ↔ 1 area



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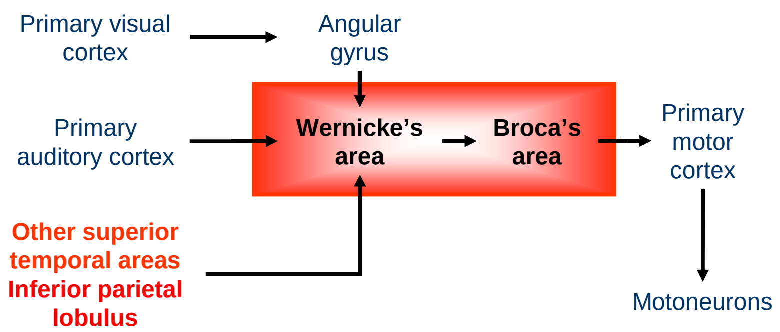
Mesulam alternative model (1980)

Hierarchised networks with complexity steps
Still two epicentres: Broca's and Wernicke's areas

Convergence concept for temporal lobe areas :
1/ long-term memory access and emotional system : anterior temporal pole
2/ meaning access : posterior superior temporal areas (supramarginal gyrus)



Perkell model of brain activation series (1980)

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Abstract representation of articulatory units

Orosensitive representations of articulatory units

PROGRAMMING OF THE ARTICULATORY UNITS
TEMPORAL CHAIN

Coarticulation organisation

Temporal adjustment of orosentive targets

PLANIFICATION OF THE ARTICULATORY UNITS
NEUROL MESSAGE TRANSMISSION

Temporal adjustment of articulatory units

ARTICULATION

Motor execution of articulatory units

Articulatory movements

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2010, Aix-en-Provence, France

The heritage of Petersen and colleagues (1988-90)

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Petersen, S.E., Fox, P.T., Posner, M.I. & Raichle, M.E. (1988). **Positron emission tomographic studies of the cortical anatomy of single-word processing**. Nature 331: 585-589.

Petersen, S.E., Fox, P.T., Posner, M.I., & Raichle, M.E. (1989). **Positron emission tomographic studies of the processing of single words**. Journal of Cognitive Neuroscience 1: 153-170.

Petersen, S.E., Fox, P.T., Snyder, A.Z., & Raichle, M.E. (1990). **Activation of extrastriate and frontal cortical areas by visual words and word-like stimuli**. Science 249: 1041-1044.

PET studies based on experimental condition substractions

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1/ Attentional fixation (symbol)
2/ Passive visual presentation of words and reading
3/ Reading and production of words

(2 – 1) = WORD READING
(3 – 1) = READING AND SPEECH PRODUCTION
(3 – 2) = SPEECH PRODUCTION

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The heritage of Petersen and colleagues (1988-90)

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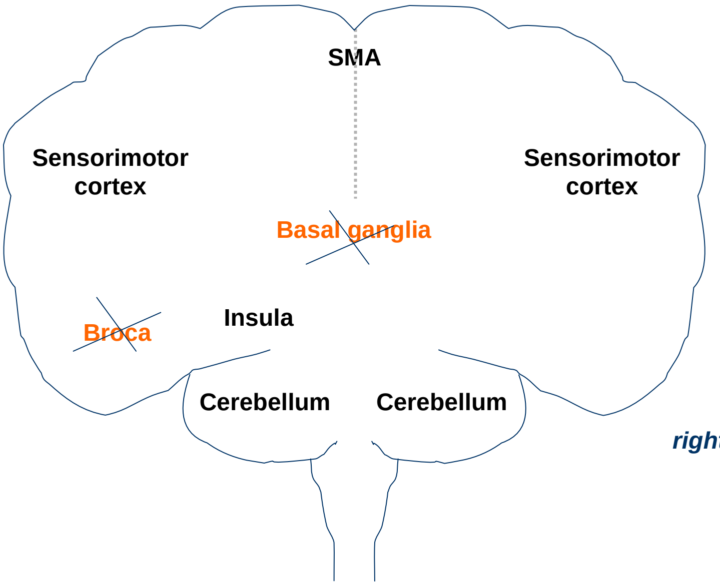

left *right*

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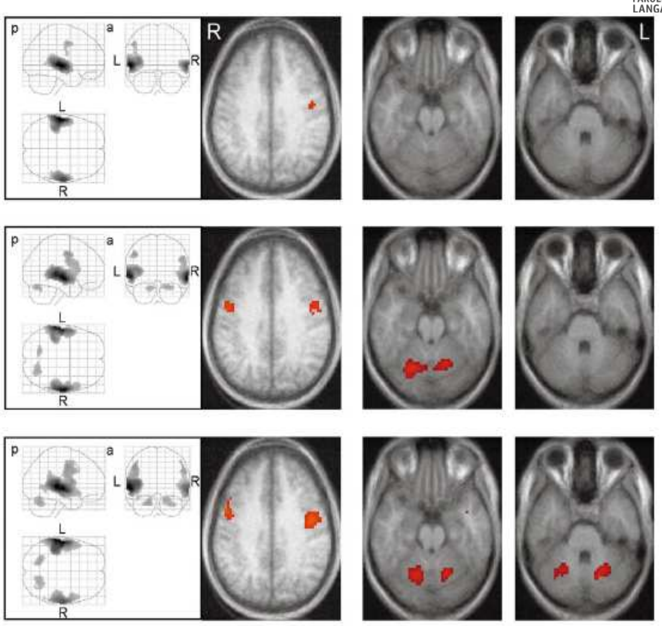
From Petersen to more recent neuroimaging studies

NeuroImage 13, 101–109 (2001)
doi:10.1006/nimg.2000.0672, available online at http://www.idealibrary.com on IDEAL®

Differential Contributions of Motor Cortex, Basal Ganglia, and Cerebellum to Speech Motor Control: Effects of Syllable Repetition Rate Evaluated by fMRI

D. Wildgruber,*† H. Ackermann,† and W. Grodd*



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From Petersen to more recent neuroimaging studies

PERGAMON

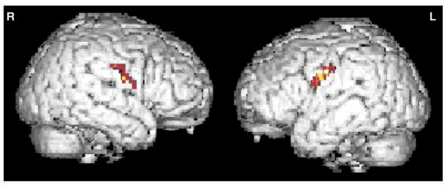
Journal of Neurolinguistics 15 (2002) 59–90

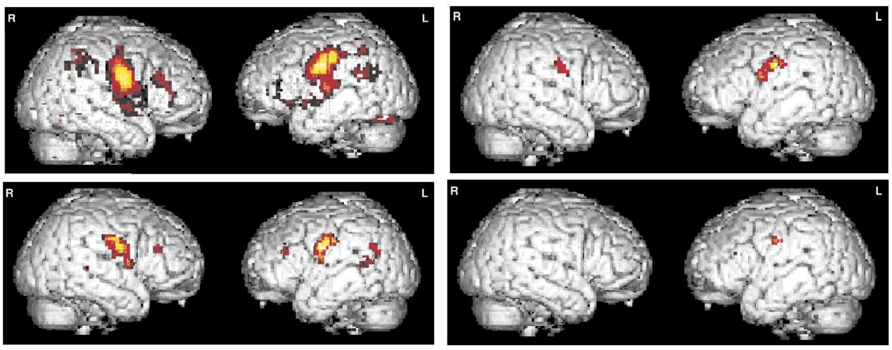
Journal of NEUROLINGUISTICS

www.elsevier.com/locate/jneuroling

The speaking brain: a tutorial introduction to fMRI experiments in the production of speech, prosody and syntax

G. Dogil*, H. Ackermann, W. Grodd, H. Haider, H. Kamp, J. Mayer, A. Riecker, D. Wildgruber





Levelt's point of view (1999): existence of a mental syllabary

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The most frequently used syllables are sufficient for the production of the major part of the verbal productions of a language

Associated by nature as the most frequently used motor activities

Not sequenced in real time
Recovered as "pre-learned" motor programs, ready-made
Stored in the mental syllabary
Ready for retrieval
New/low-frequency syllables are assembled online segment by segment

Retrieval of these frequent motor performances could reduce the processing time necessary for speech production

This mental lexicon might be localised within the premotor cortex

Speech production processes and pathological bases

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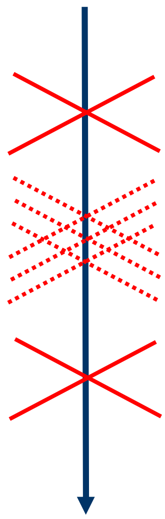
Higher-order
motor programming
temporal planification

Lower-order
motor execution

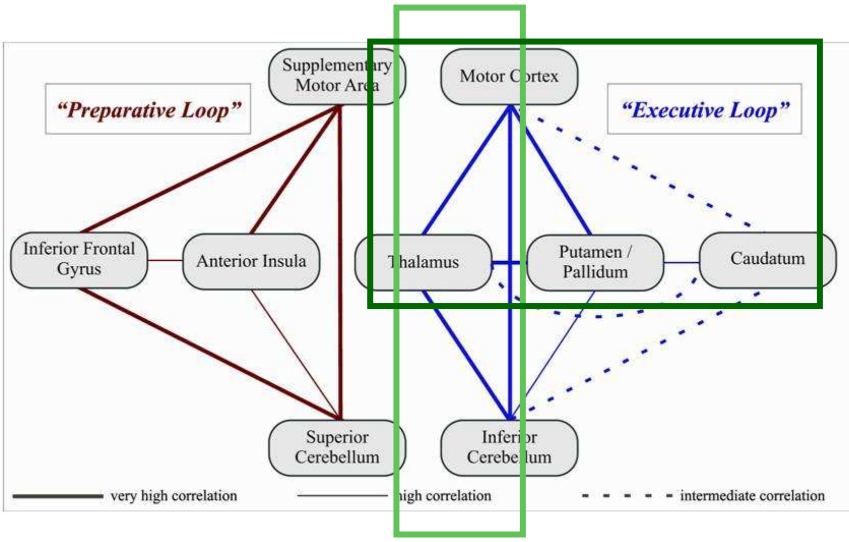


APRAXIA

DYSFLUENCIES

DYSARTHRIAS

Riecker and Ackermann contribution (2005)



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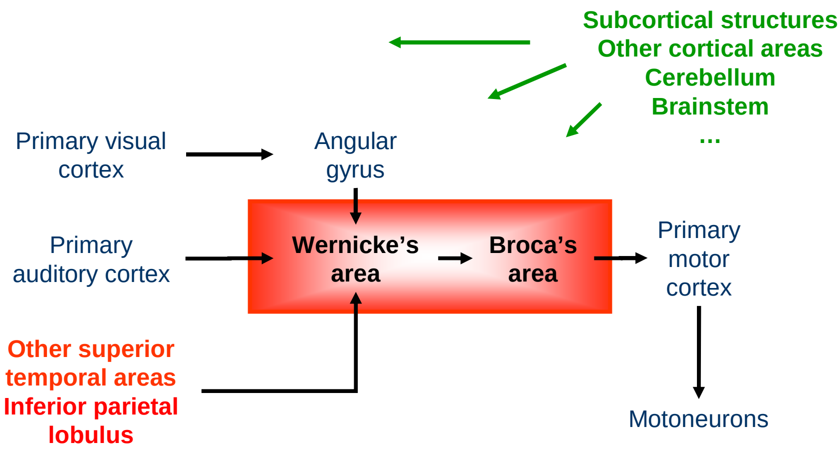
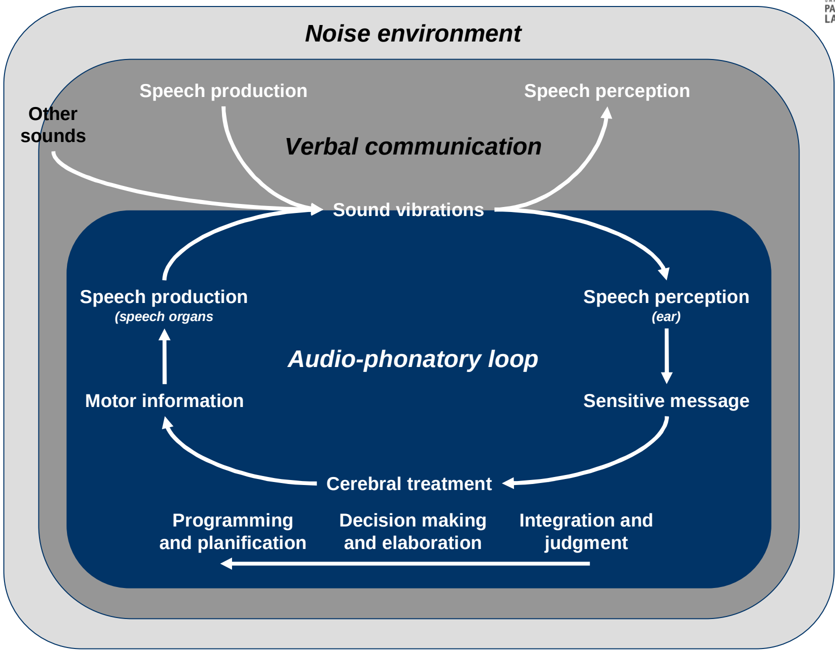
Current opinion of speech production models

Reject of classical localisationist models
Distribution on areas anatomically distinct, integrating the information in parallel

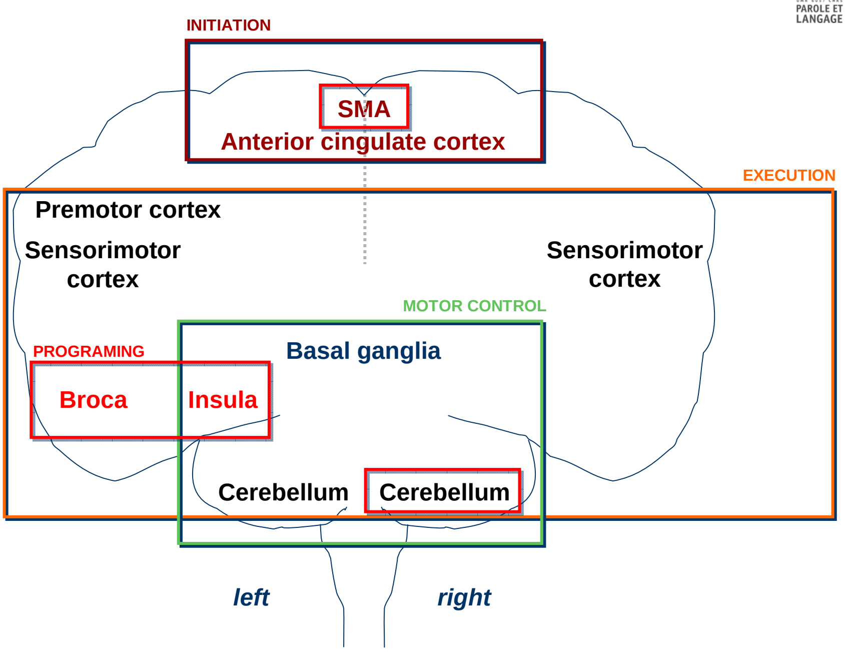
Localisation of primary functions (audition, articulation)
No precise attribution of functions to structures



Speech production as part of a global communication system



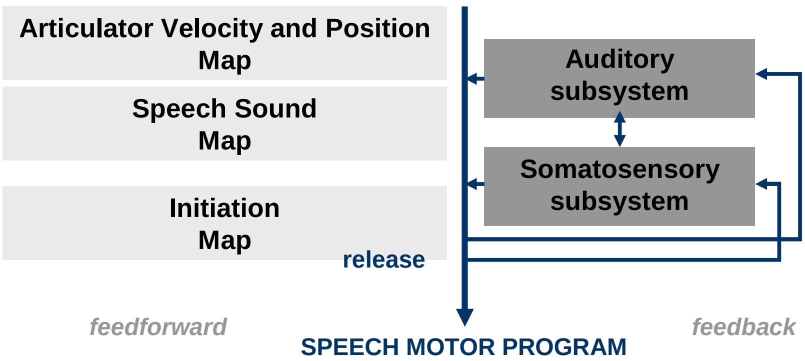
Speech production as part of a global communication system



DIVA model (since 2006)

Directions Into Velocities of Articulators
Neural network model of speech production
Link speech processes both computationally and neurophysiologically
(Guenther *et al*., 2006; Golfinopoulos *et al*., 2009)

Learning of the required movements inducing overt speech production from a computerised-simulation vocal tract (Maeda, 1990, modified)



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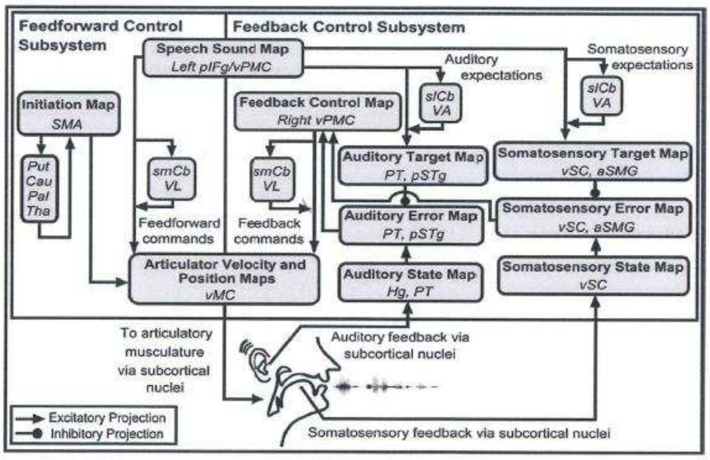
DIVA model (since 2006)

Functional neuroimaging
Neural networks localisation for each of the speech production steps



DIVA model (since 2006)

« The minimum speech motor execution network »

Mesiofrontal areas
Intrasylvian cortex
Pre- and postcentral gyri
Left inferior posterior frontal cortex
Basal ganglia
Cerebellum
Thalamus

syllable repetitions, production of pseudowords or even isolated vowels

Some conclusions

Neural control of speech production
- complex
- distributed
- specific
- hierarchy

Functional neural substrates
- not clearly defined
- subject to modification
- part of the modelling

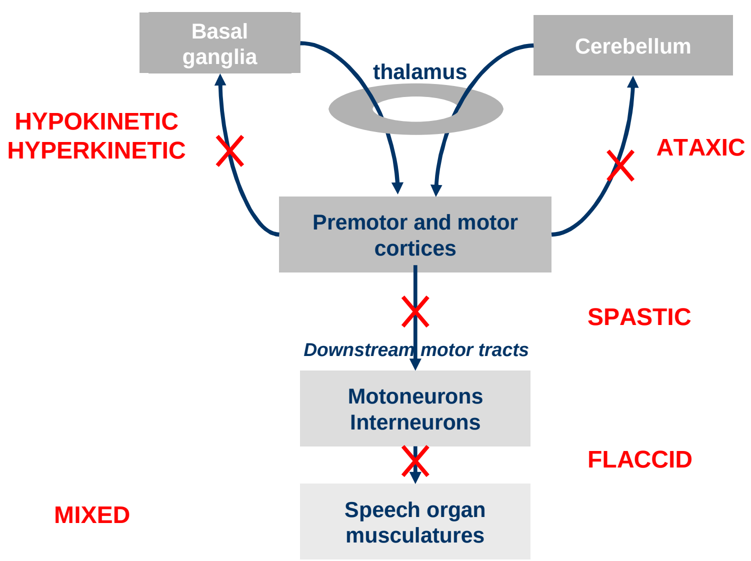
Motor speech disorders
- plasticity, compensation, reorganisation
- effect of changes (medication, surgery, behavioural, other)

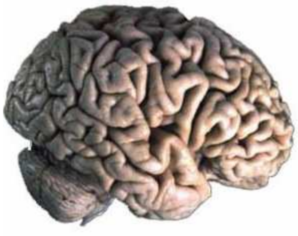
What about dysarthric speech?

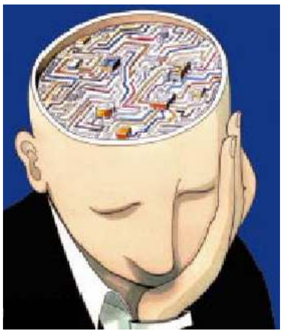
"Dysarthria is a collective name for a group of neurologic speech disorders resulting from abnormalities in the strength, speed, range, steadiness, tone, or accuracy of movements required for control of the respiratory, phonatory, resonatory, articulatory, and prosodic aspects of speech production. The responsible pathophysiologic disturbances are due to central or peripheral nervous system abnormalities and most often reflect weakness; spasticity; incoordination; involuntary movements; or excessive, reduced, or variable muscle tone"

Duffy, 2005, *Motor Speech Disorders*, p.5, from Darley *et al*., 1969

What about dysarthric speech?







Do we need a brain network model for the understanding of dysarthrias and basal ganglia speech disorders ?