Oral Constriction Gestures I
Constriction Degree and Sound Sources

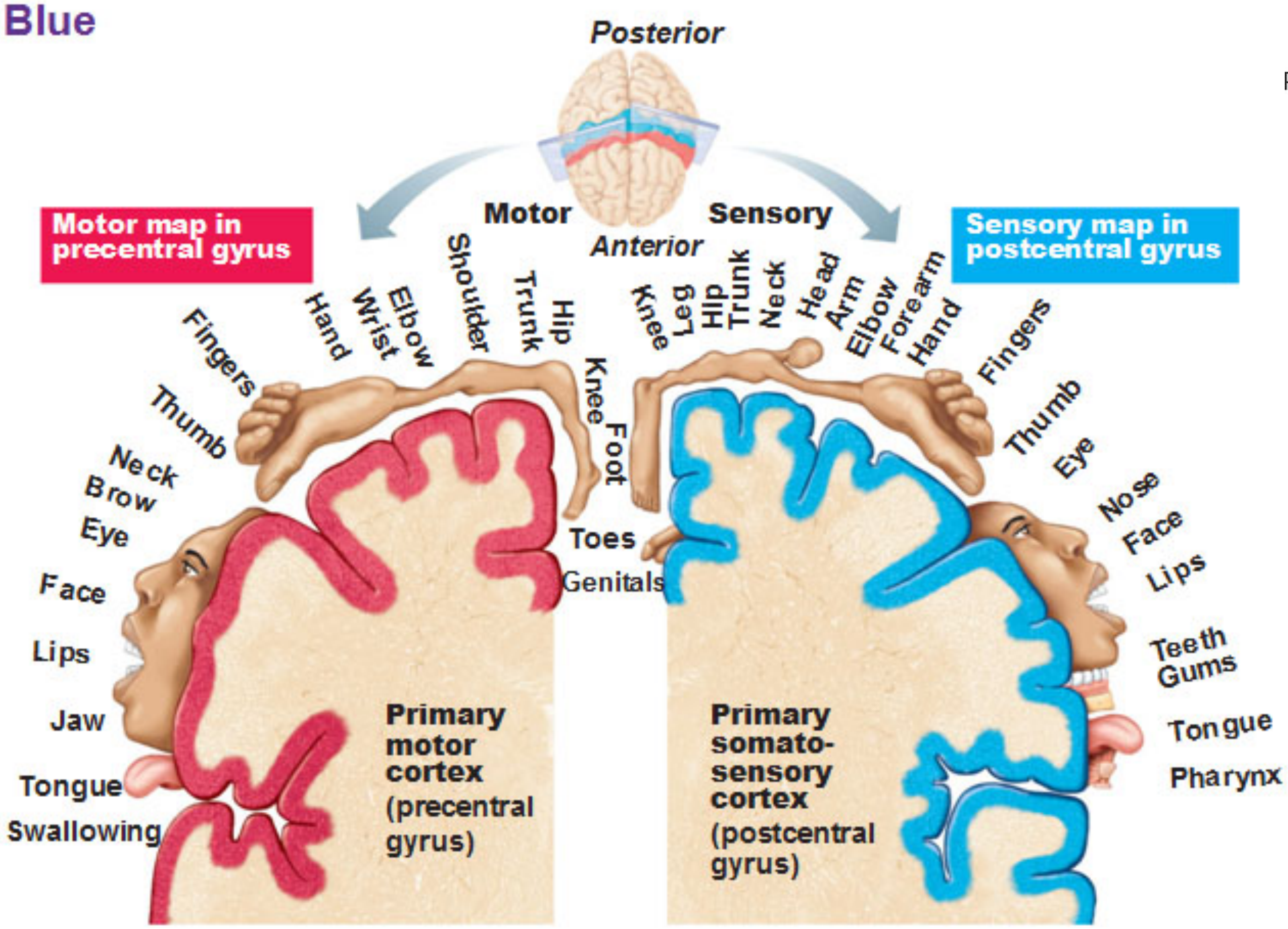
Contrasting Oral Constriction Gestures

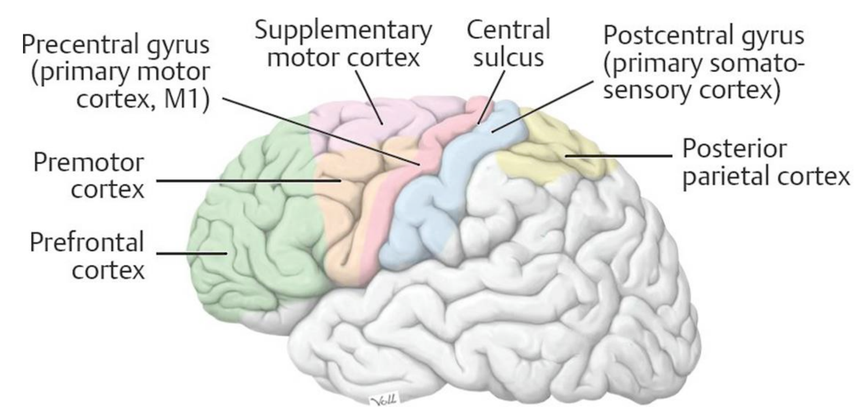
- Conditions for gestures to be informationally contrastive from one another?
  - shared across members of the community (parity)
  - not confusable with one another under a variety of speaking conditions.
- Anatomically distinct constricting organs meet criterion
  - lips
  - tongue tip
  - tongue dorsum
- Shared by all members of the community
- Decomposition of body into distinct organs is at least partially innate.
- These contrast in all languages.

Sensorimotor "homunculus"

Homunculus of Primary Somatosensory Cortex in Blue

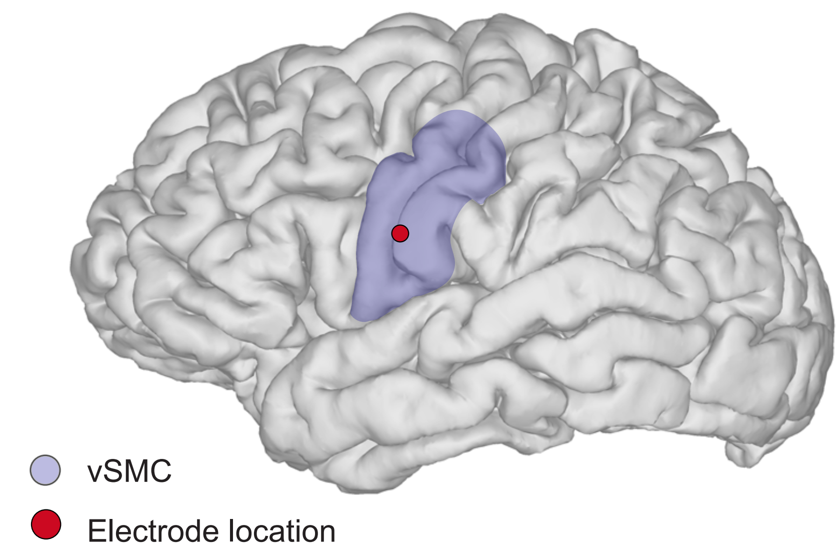
Note that each hemisphere receives info from the opposite side of the body





Coding in ventral sensorimotor cortex (vSMC) while speaking

- Electrocorticography (ECoG) application of a mesh of tiny electrodes directly on the surface of the brain of a patient who is being prepared for brain surgery.
- Allows recording from very small populations of neurons.
- Developed at UC San Francisco in Edward Chang's lab
- Examine multiple sites in vSMC (ventral Sensory Motor Cortex) *while patient is speaking*.
- Test which descriptions of speech best predict patterns of activation in particular electrode locations.

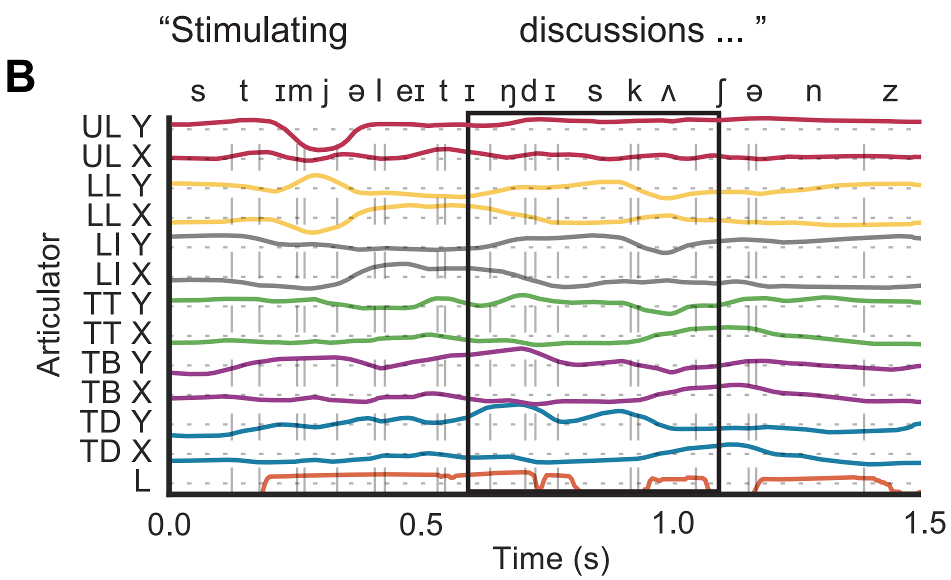


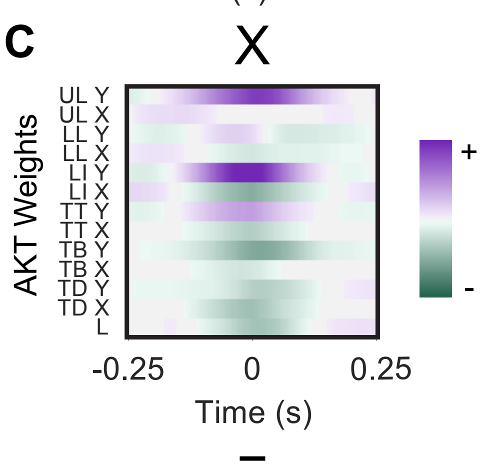
- 460 read sentences (MOCHA-TIMIT)
- 5 participants
- Pseudo-EMA kinematics
- 130 electrode sites (across participants)

Josh Chartier, Gopala K. Anumanchipalli, Keith Johnson, Edward F. Chang (2008). Encoding of articulatory kinematic trajectories in human speech sensorimotor cortex. *Neuron.*

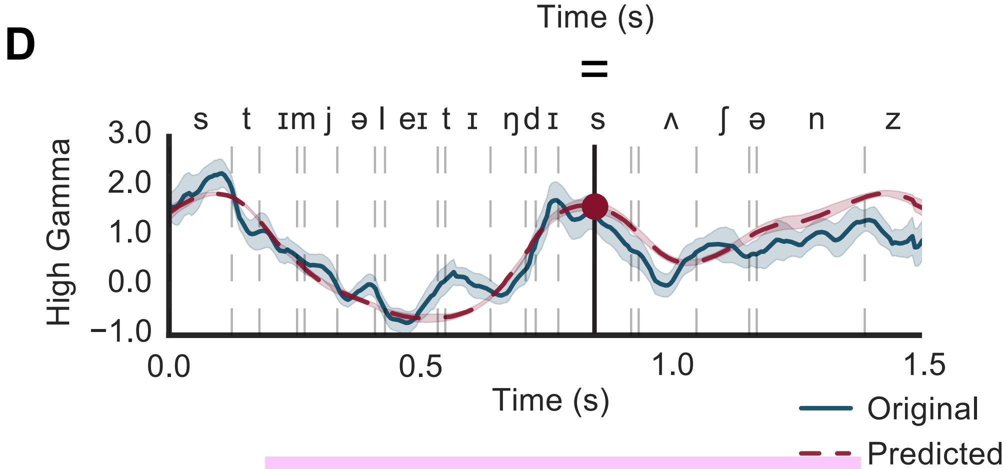
Example from one site

EMA time functions
(estimated from acoustics)

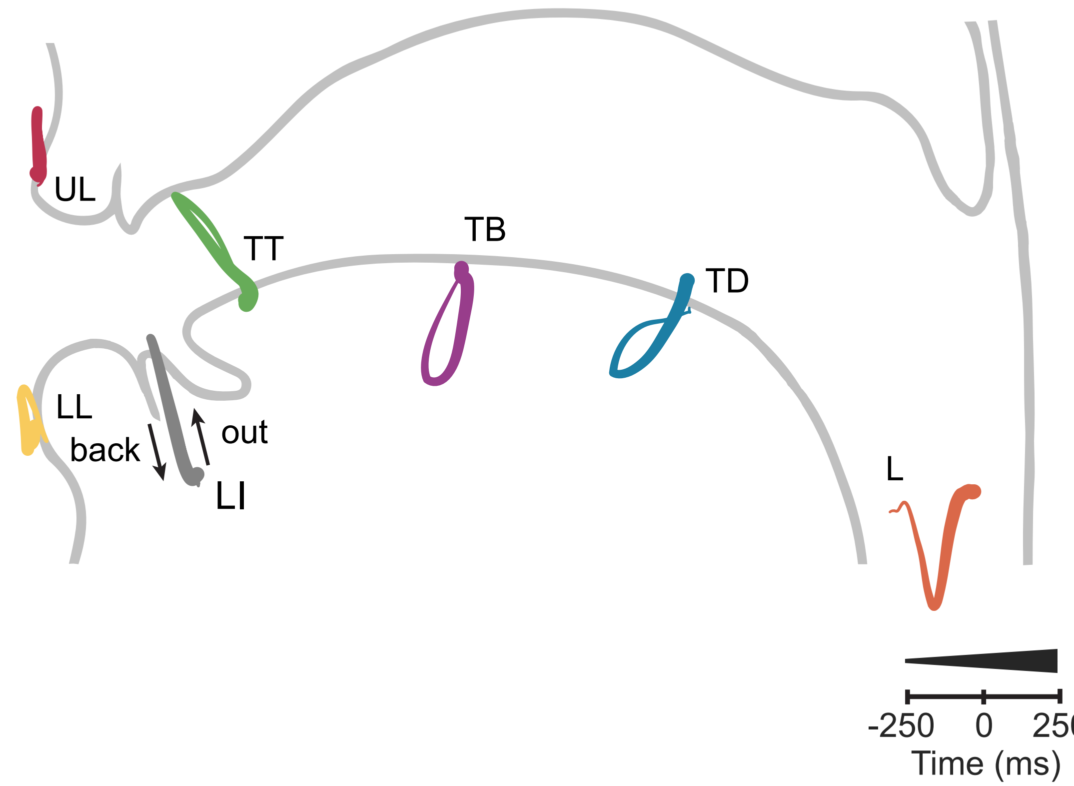




Weights

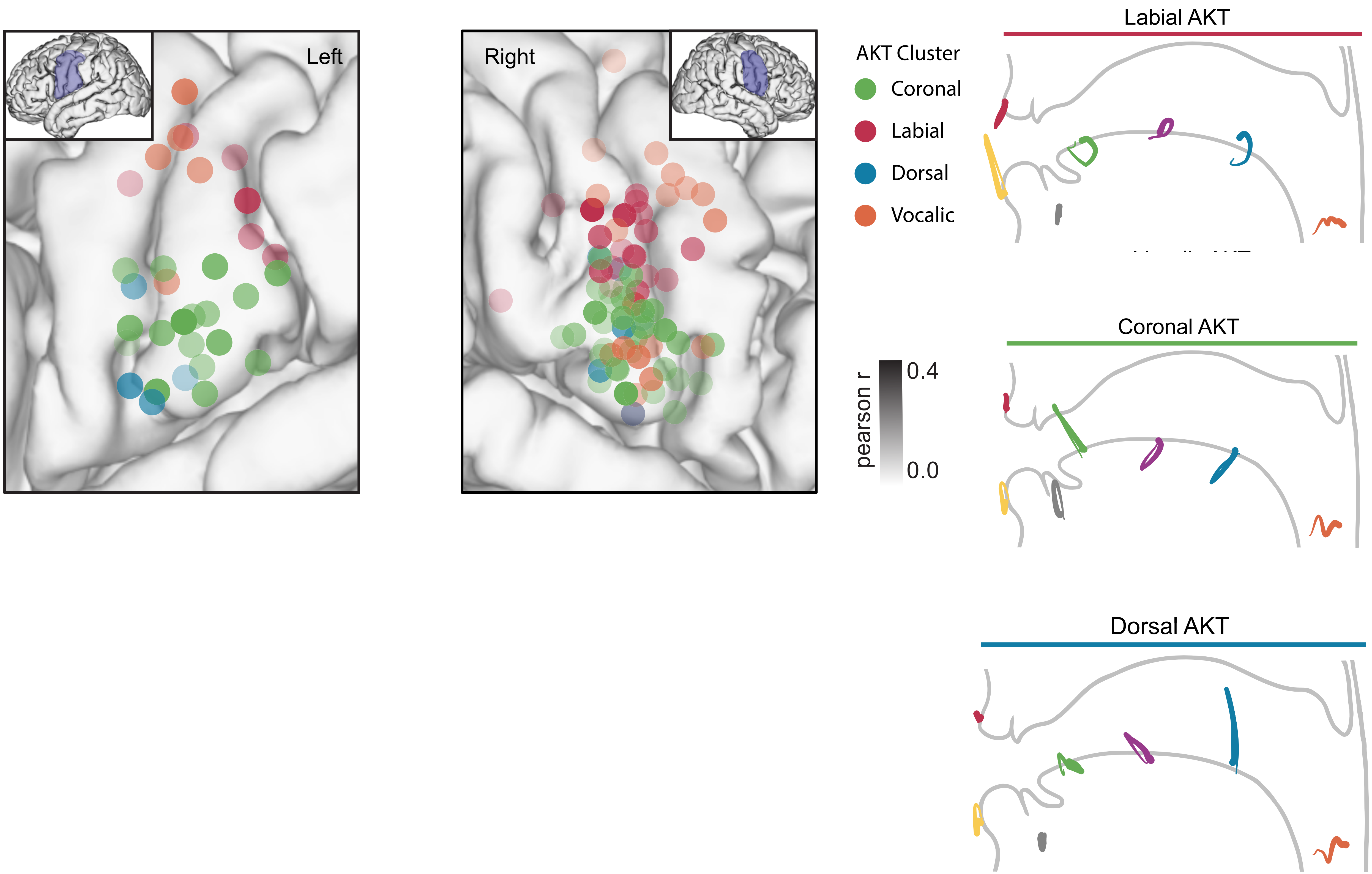


Electrode Activity



Weight pattern corresponds to coordinated articulator motion that produces and releases a coronal constriction.

Sites code distinct constricting effectors



Facial mimicry in neonates

- Puzzling to understand
- No opportunity for learning though feedback
    - Infant can't see his/her own face.
    - How does an infant's face come to match that of a caregiver interacting with them.
- Possible to observe in babies only 10 minutes old

Examples of Early Mimicry

Tongue Protrusion

Mouth Opening

Lip Protrusion

Meltzoff and Moore, 1977

Sensorimotor Integration of ora-facial system

How are humans able to use sensory information to specify bodily movement?

- Human infants (even neonates) are capable of oro-facial mimicry.
- Facial mimicry is remarkable in that:
  - Infant cannot see its own face.
  - Infant cannot feel the models' face.
  - *Infant may not get the gesture entirely correct, but almost always chooses the right organ*

Differentiation of Oral Gestures: Constriction Degree (CD)

- potential continuum
- how is it partitioned into discrete regions that are contrastive across speakers?

Quantal Theory of Speech (Stevens, 1968, 1989)

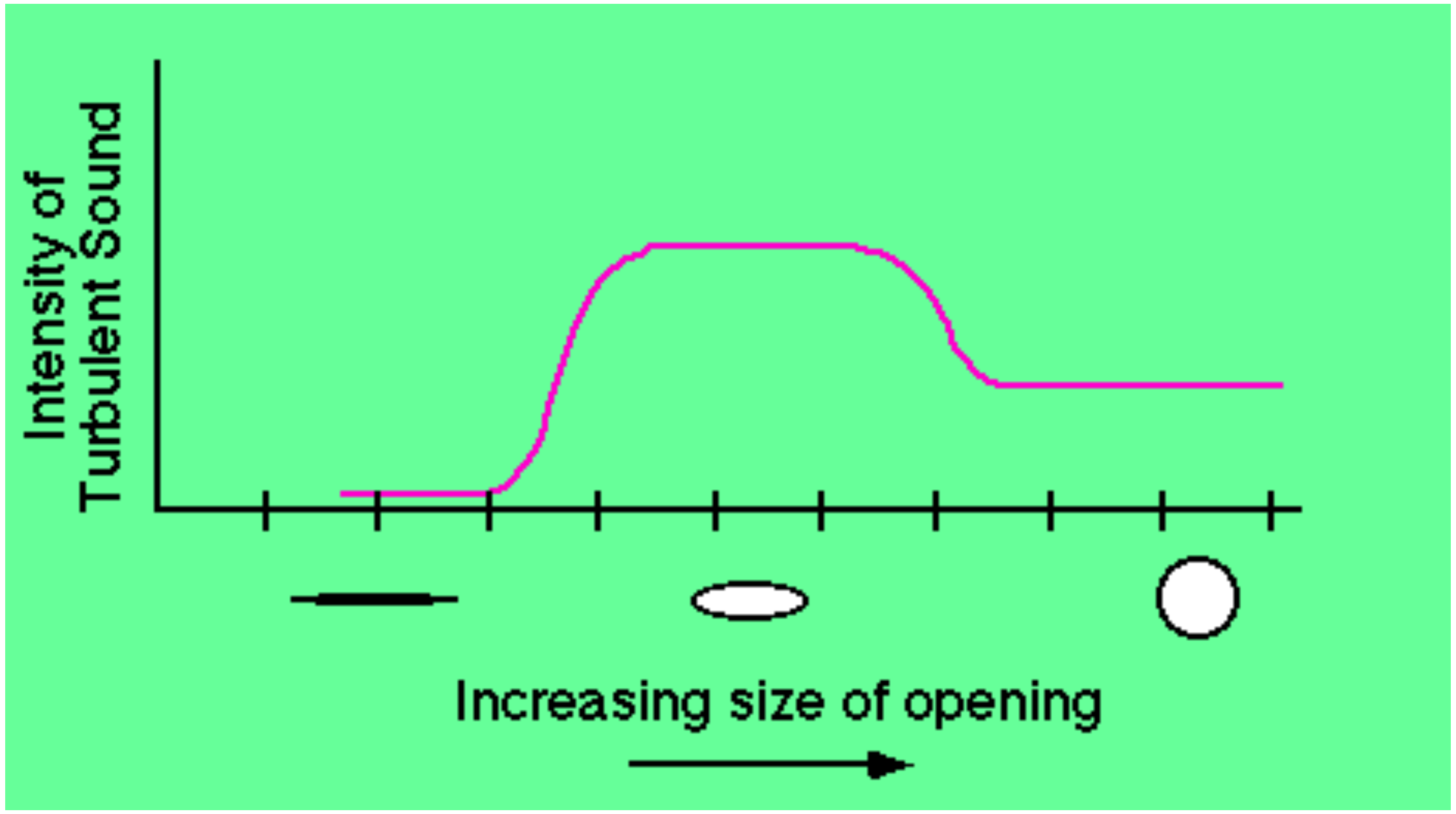
- map of the relation between:
  dimensions of physical device and sound produced
- relation is non-linear
  - Regions of map where small change in dimensions do not effect sound
  - Regions of map where small change in dimensions cause jump in sound

Experiment with a straw

1. Blow gently into straw, so it makes only soft noise.
2. Start gradually narrowing just behind tip of straw.
3. At some point, sound will suddenly become loud and/or high pitched.
4. Loud sound will remain until straw is tightly pinched.

Results of experiment: map relating opening and sound

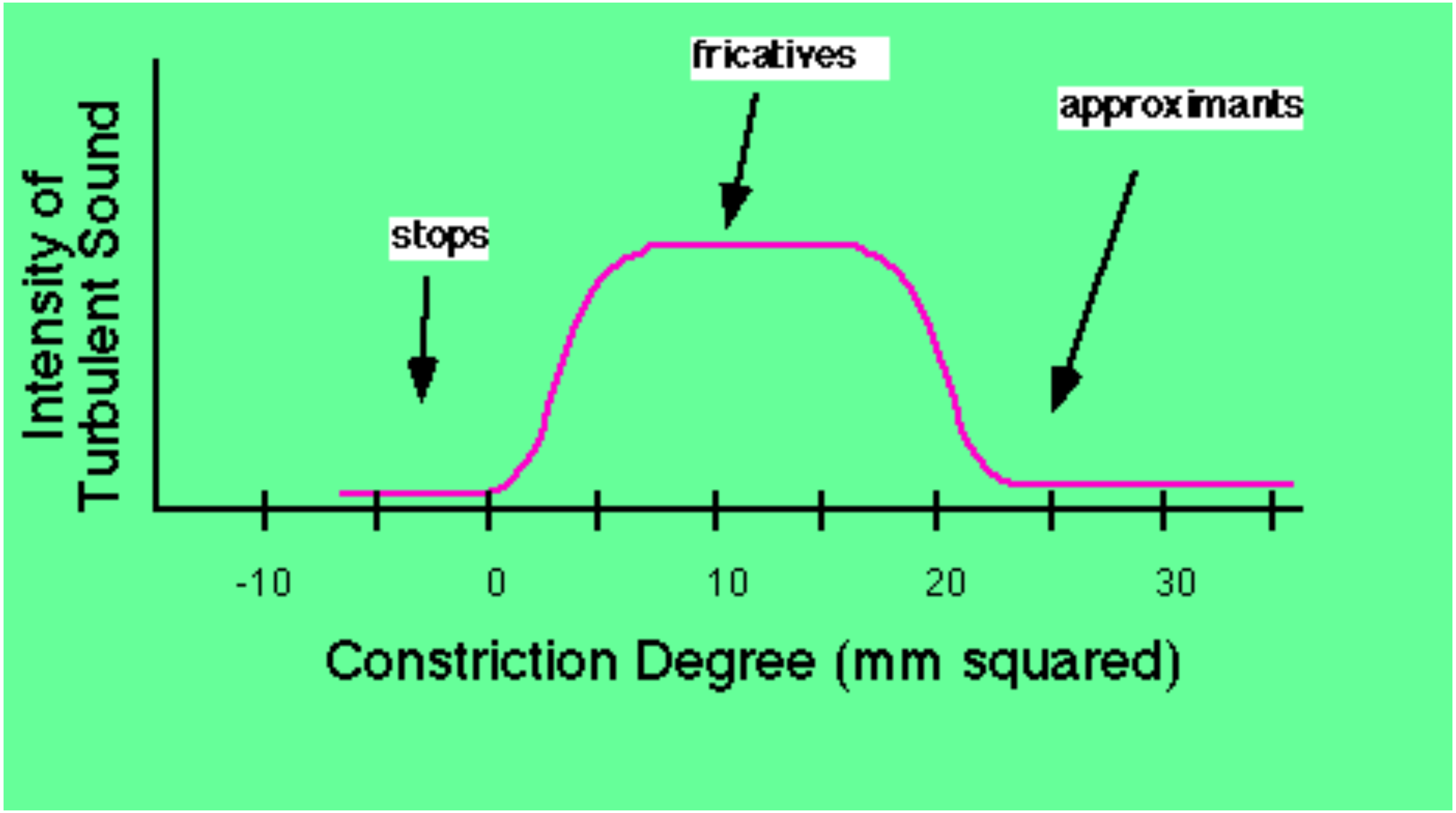
- Stable regions
  Small change in opening do not effect sound
- Transition regions
  Small change in opening shifts from one stable region to another.



Stevens' Quantal Theory

- Stable and transition regions generally characterize relations between dimensions of sound producing devices and the sounds they produce.
- This is true of the human vocal tract.
- The nonlinear nature of this map partitions a potential gestural continuum into distinct stable regions.
- Languages employ contrastive gestures that are produced in distinct stable regions of the map relating articulation and sound. why?

Example: Constriction Degree



Interaction of Constriction Degree and Voicing

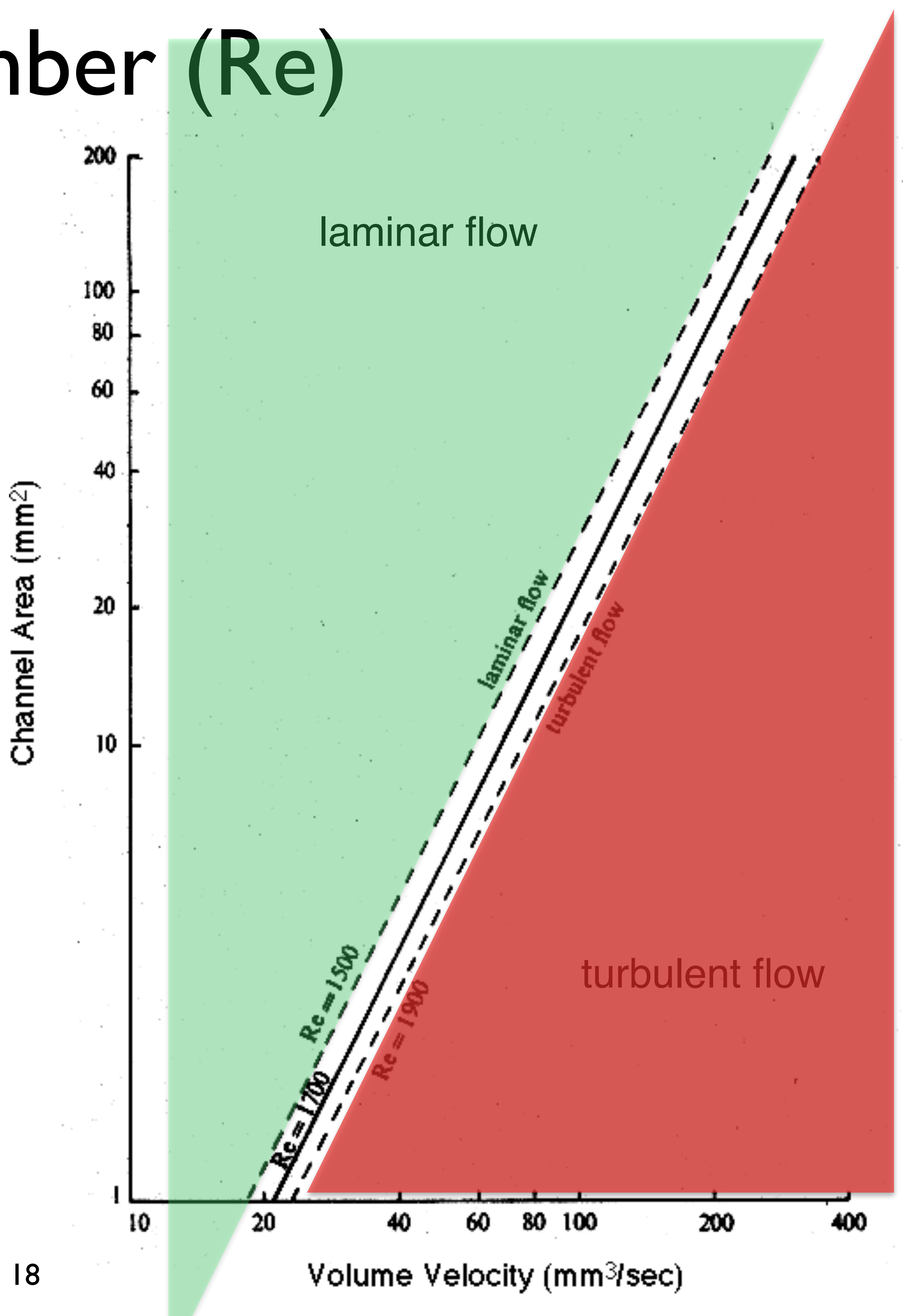
- New Experiment:
  1. Produce [v]
  2. Widen constriction until turbulence disappears.
  3. Now stop voicing
  4. Turbulence is back, why?

Turbulence

- Turbulent flow of a liquid (or gas) involves generation of random (or chaotic) patterns of molecular vibration.
- Laminar flow does not generate turbulence,
- State of system (which attractor) depends on:
    - Channel size
      Narrower channels more readily cause turbulence.
    - Volume velocity (cm^3/sec) of airflow
      Higher airflow rates more readily cause turbulence

Reynolds Number (Re)

- Dimensionless quantity that takes both channel size and volume velocity into account (and other parameters like temperature and density of air that don't change much in the vocal tract).
- A given channel area (CD, constriction degree) will have different Reynold's number (Re), depending on the volume velocity of the flow.
- Turbulent flow will result at a particular Re threshold (for speech conditions, Re=1700), and the intensity of the generated turbulence will increase linearly as Reynolds number increases above threshold.



From: Catford, 1977

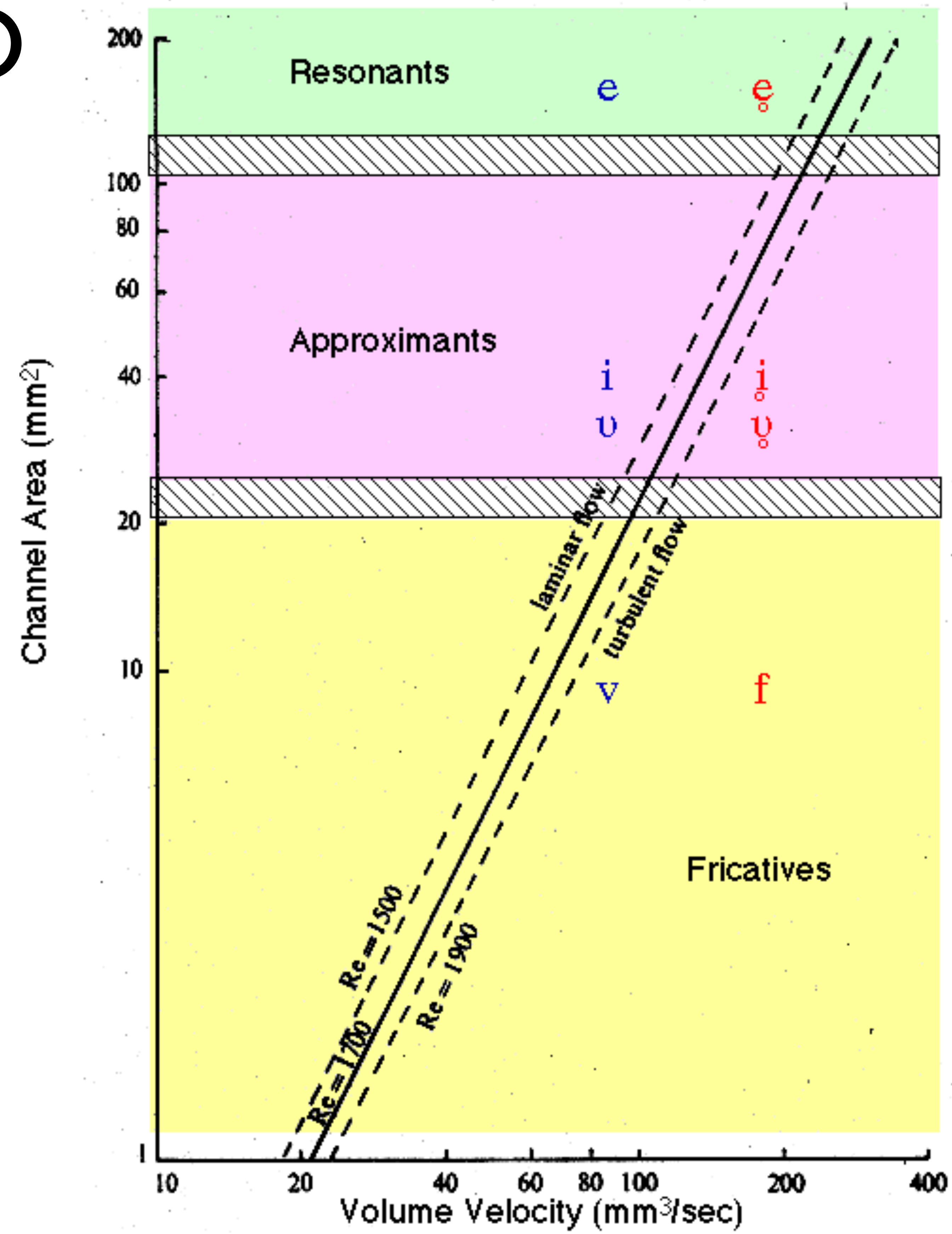
Voicing reduces volume velocity

- Glottis is closed roughly half the time.

CD	Re
$CD < 20\ mm^2$	$Re > 1700$
$20 < CD < 100\ mm^2$	$Re > 1700$ for voiceless flow $Re < 1700$ for voiced flow rates
$CD > 100\ mm^2$	$Re < 1700$

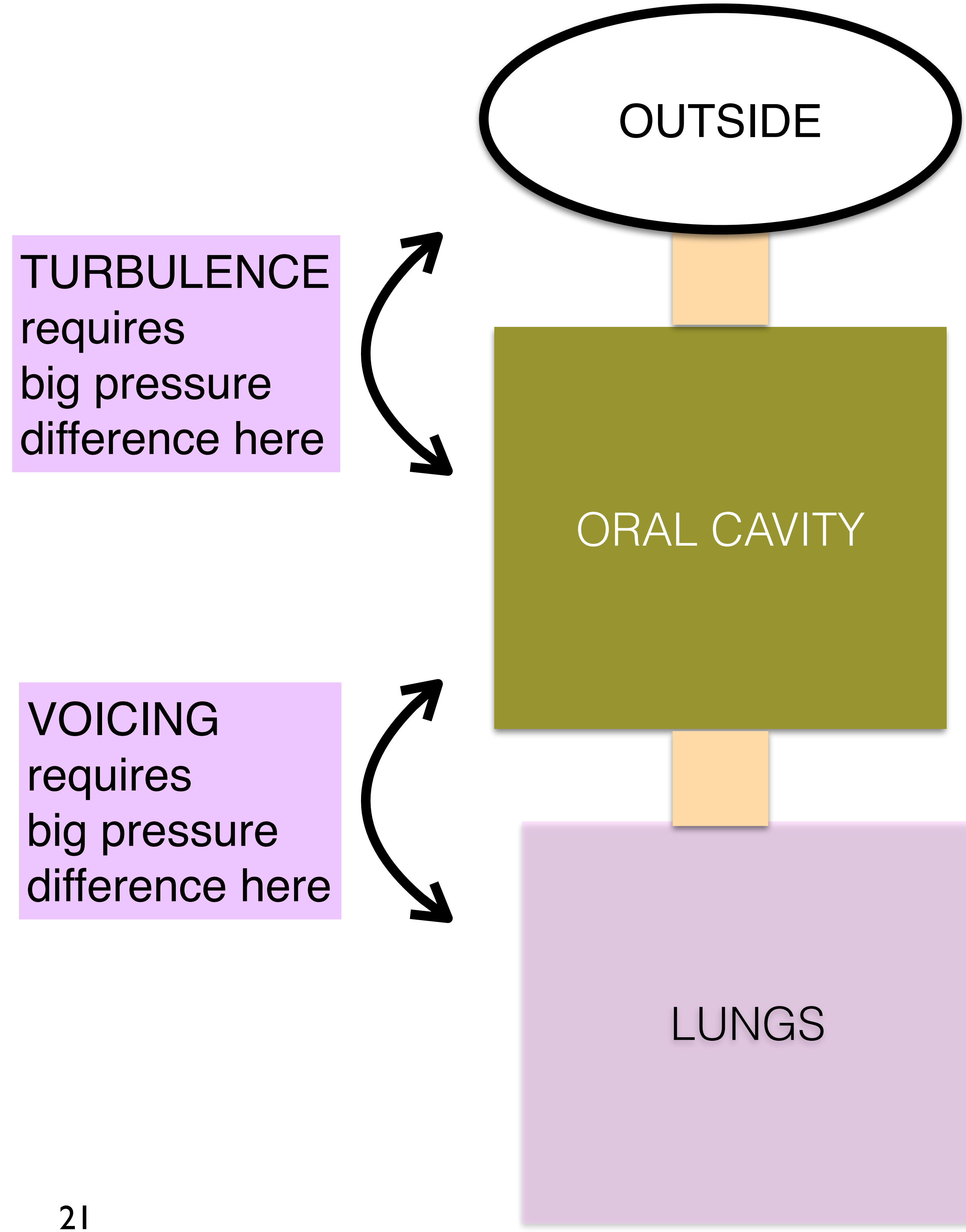
Classification of CD Catford

stop	no flow
fricative	turbulent flow
appoximant	turbulent flow iff voiceless
resonant	laminar flow



Instability of Voiced Fricatives

- Voiced fricatives are statistically rare in the languages of the world
- Aerodynamic requirements of turbulence and voicing are at cross purposes.
- What happens to them?
- devoicing
  to preserve turbulence, voicing may be lost
- loss of turbulence
  to preserve voicing, constriction degree may increase



Lateral Fricatives

- Zulu

Trills

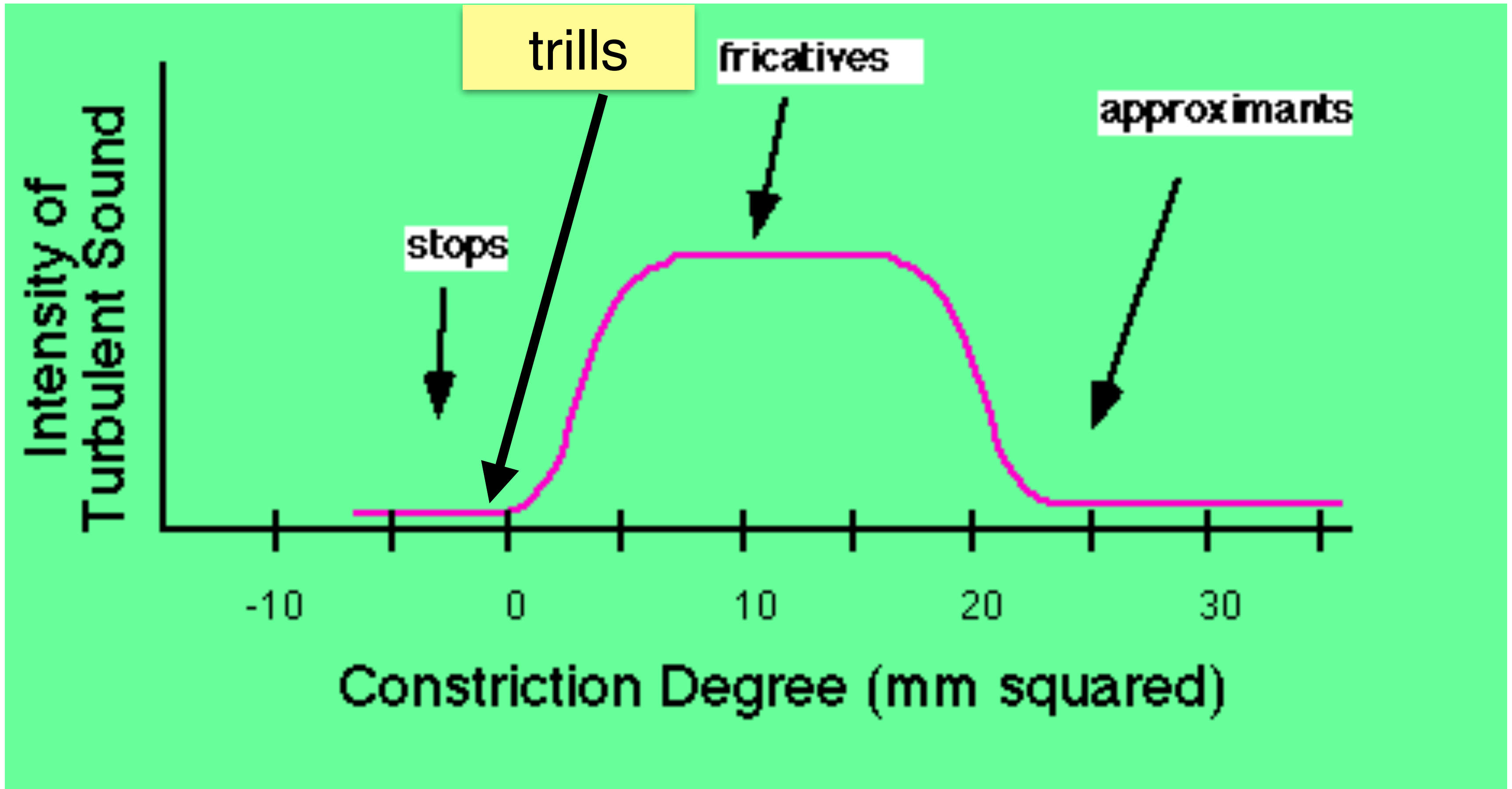
- aerodynamic phenomenon
- depends on:
  - airflow
  - constriction degree
  - articulator tension
- Constrictors that can trill:
  - lips labial
  - tongue tip coronal
  - soft palate uvular
- MRI examples (frame rate is not quite fast enough)
  - gargling

Dutch

[Rot]   ‘red’

Constriction Degree of trills

- intermediate between stop and fricative
- Articulators touch, but are not compressed
- Stability of trills



Summary of Constriction Degrees

Catford, 1977