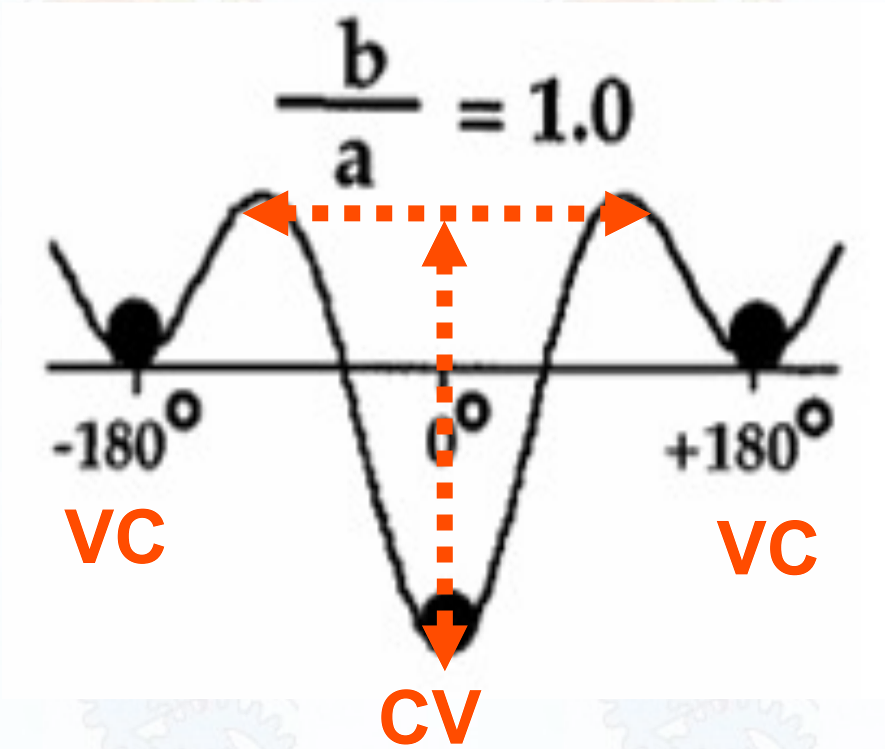
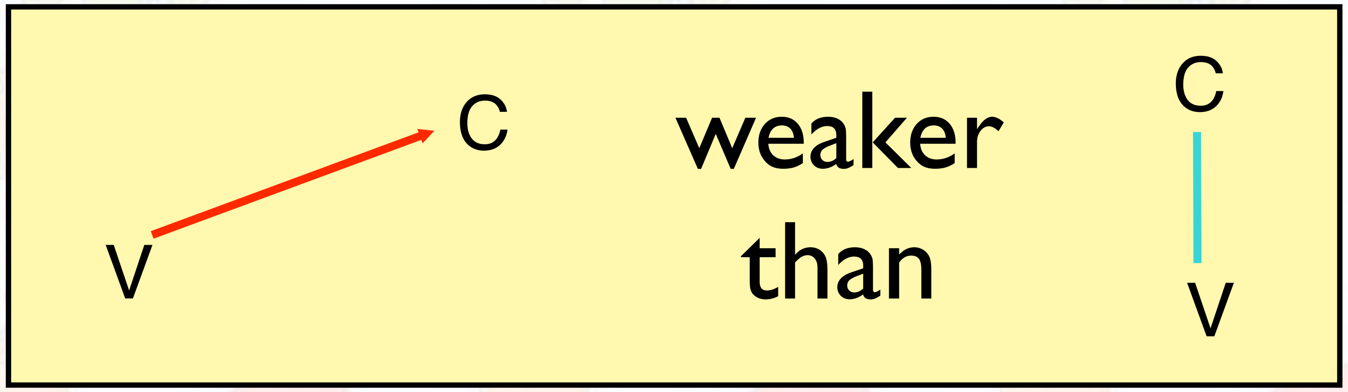
Onset vs. Coda Clusters





Consequences of strength difference:

- Planning time
- Acquisition
- Topology difference
  - C-center
  - variability
  - weight

CC in onset vs. coda: possible coupling graph differences

- Hypothesis: No competitive coupling in coda for English
  - Less stong V-C coupling doesn't attract more distant c

- Can account for differences between onset and coda in:
  - timing (c-center)
  - syllable weight
  - variability

Weightlessness of Onsets

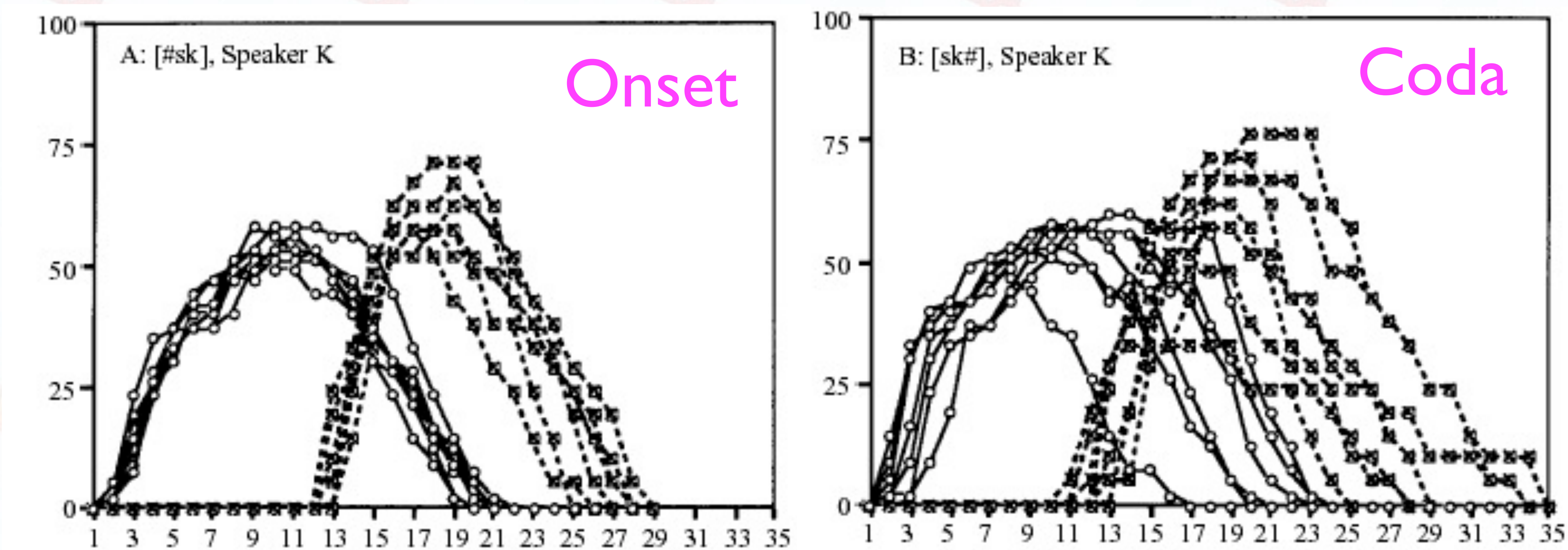
- Onset Cs typically do not contribute to syllable weight.
- Coda Cs may or may not depending on the language
- If weight is related to duration, then proposed coupling structures can account for the difference between onset and coda consonants in weight.
- With synchronous onset coupling, effect of rightward shift is that adding Cs to onset does not increase syllable duration as much as when such coupling is lacking.

- Languages in which coda Cs do not bear weight are predicted to show competitive coda coupling.

Timing stability: onsets vs. codas

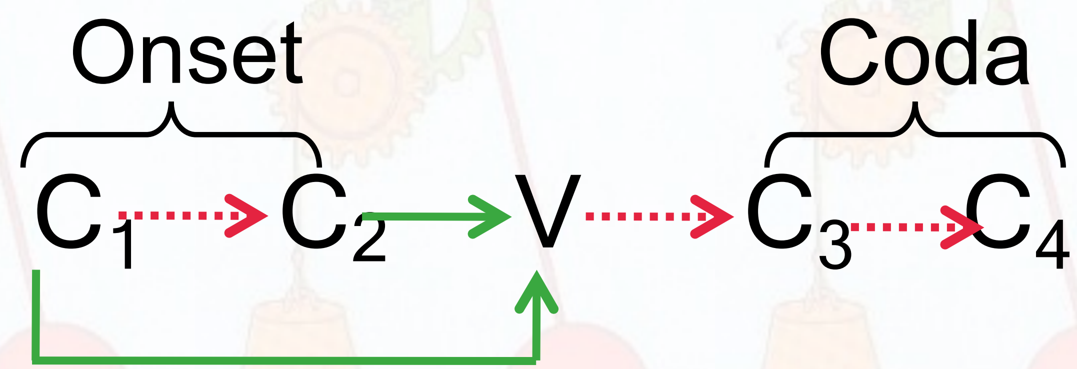
- Timing between C gestures is more stable in onset clusters than in coda clusters (Byrd, 1996).

/sk/



Graph Structure: Steady-State Relative Phases, "Competition" and Loop Constraints

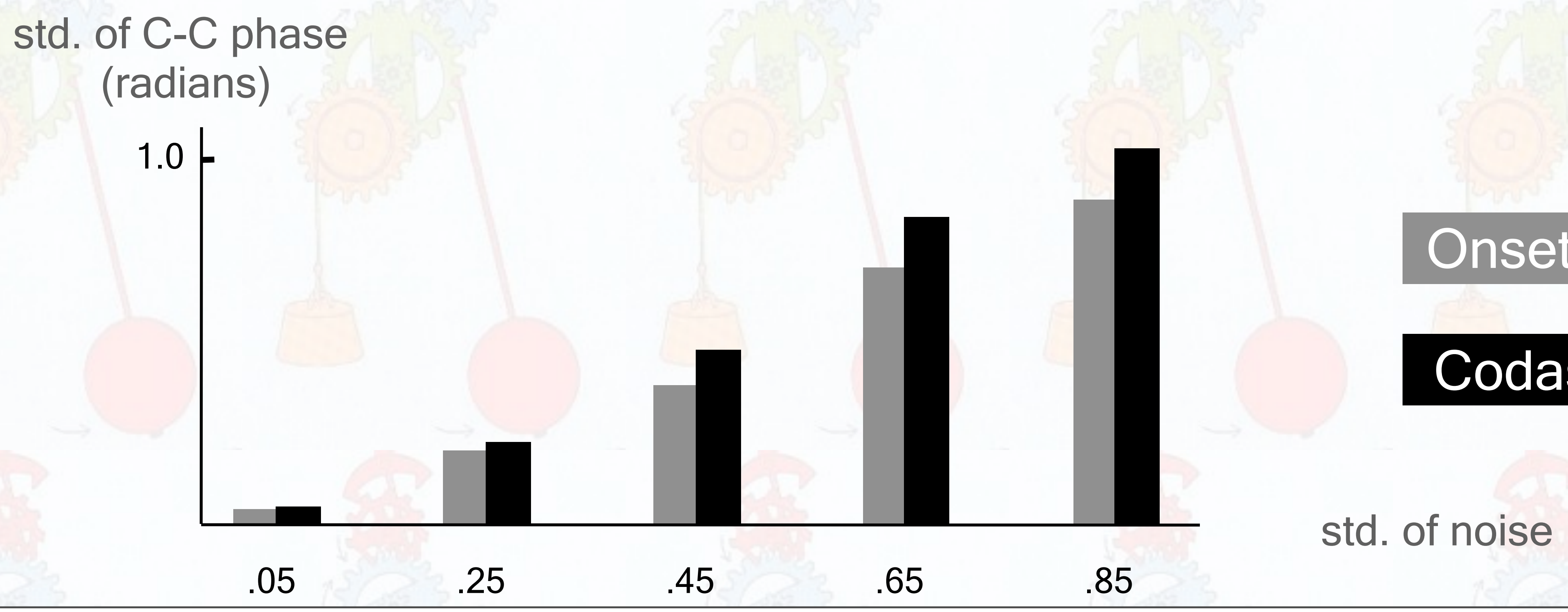
- Steady-state relative phase values are influenced by graph topology



- Codas: Open chains or tree-structures
  - all target relative phases can be attained
  - no "competition" between target relative phases
- Onsets: Closed loops add constraints
  - only target relative phase patterns compatible with loop constraints can be attained
  - "competition": resultant steady-state relative phase pattern is an overconstrained, least-squares solution that minimizes potential energy associated with interoscillator coupling forces.
  - loop constraint equations can be derived from the geometry of the incidence matrix.

Speech Simulation Results II: Greater Stability for Onsets

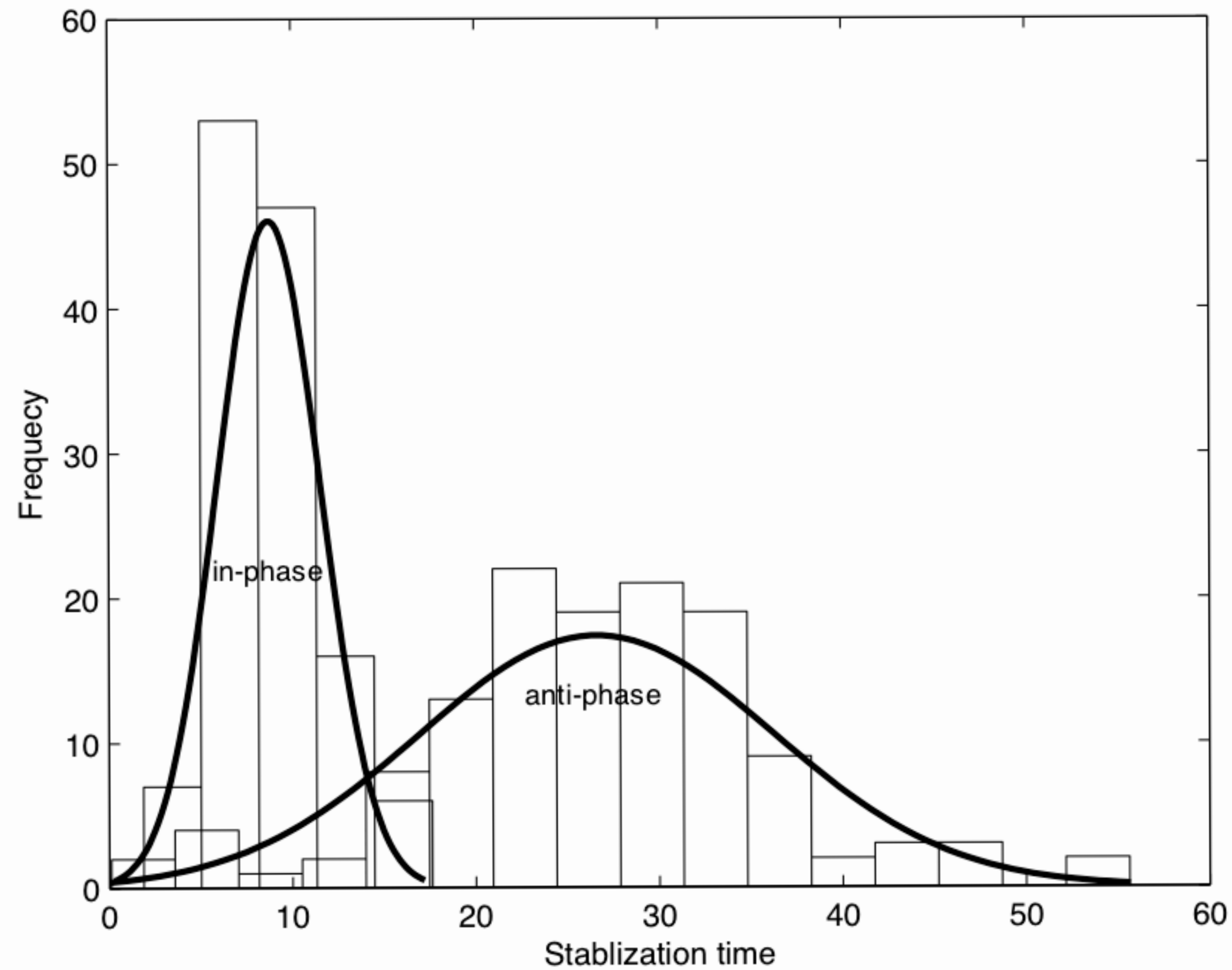
- Add noise to simulations using 5 node + 5 link graph
  - Noise source: ξ_i (t) = Gaussian, zero mean, unit variance
    - st.dev. of noise ("strength"), β, varied across conditions
    - $\beta\, \xi_i$ (t) added as acceleration forcing term to each component oscillator
- Result: Greater steady-state relative phase stability (*lower standard deviation*, σ_{ss}) for clusters in onsets than codas



Settling Time: Simulations (Nam)

- Because the in-phase attractor has a steeper well, its coupling strength is stronger.
- Relative phase settles at its target more quickly (Schöner et al, 1985)

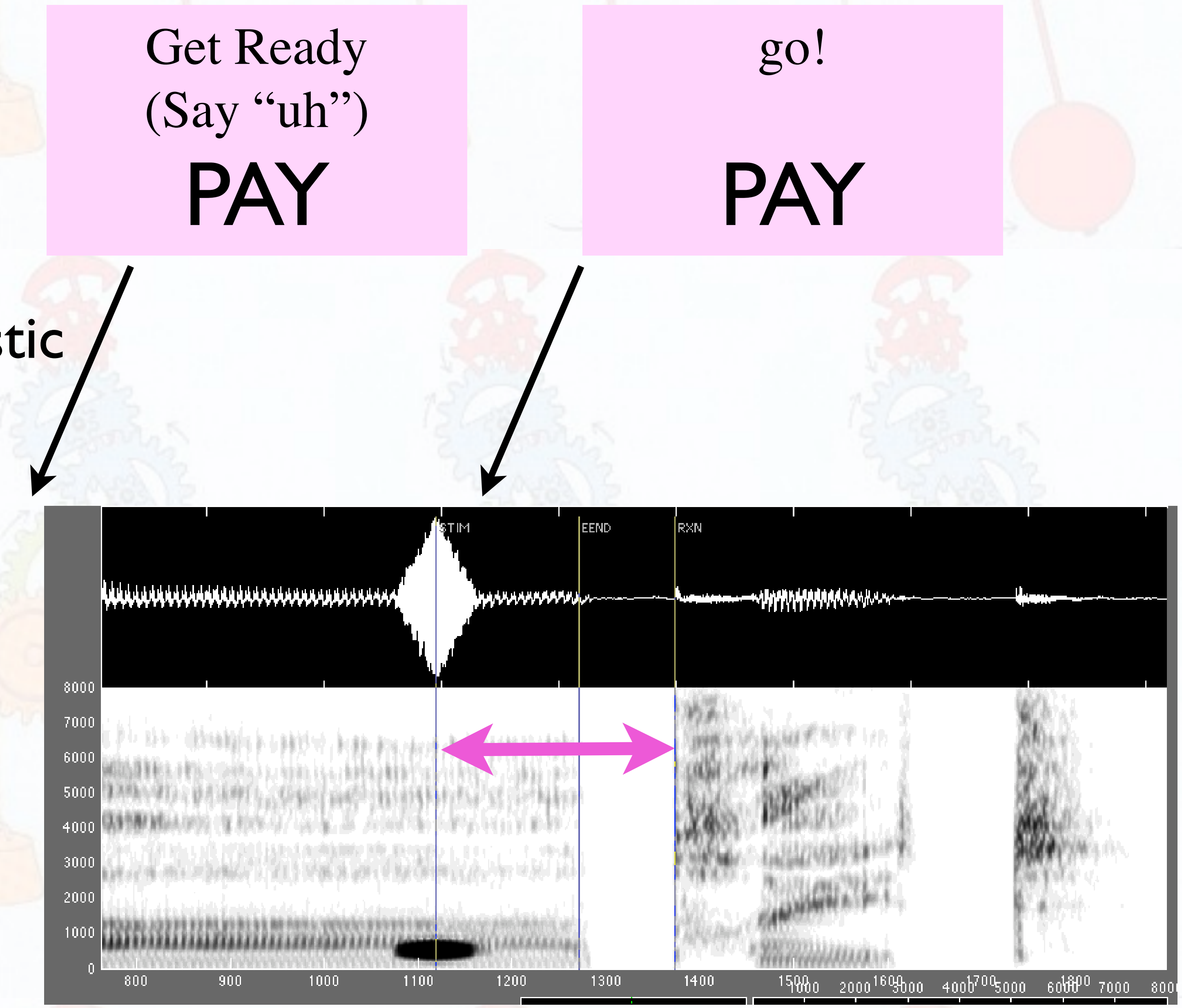
- Results of 150 simulations each of
  - in-phase (3X stronger coupling)
  - anti-phase
- Random starting phases



Planning time experiments

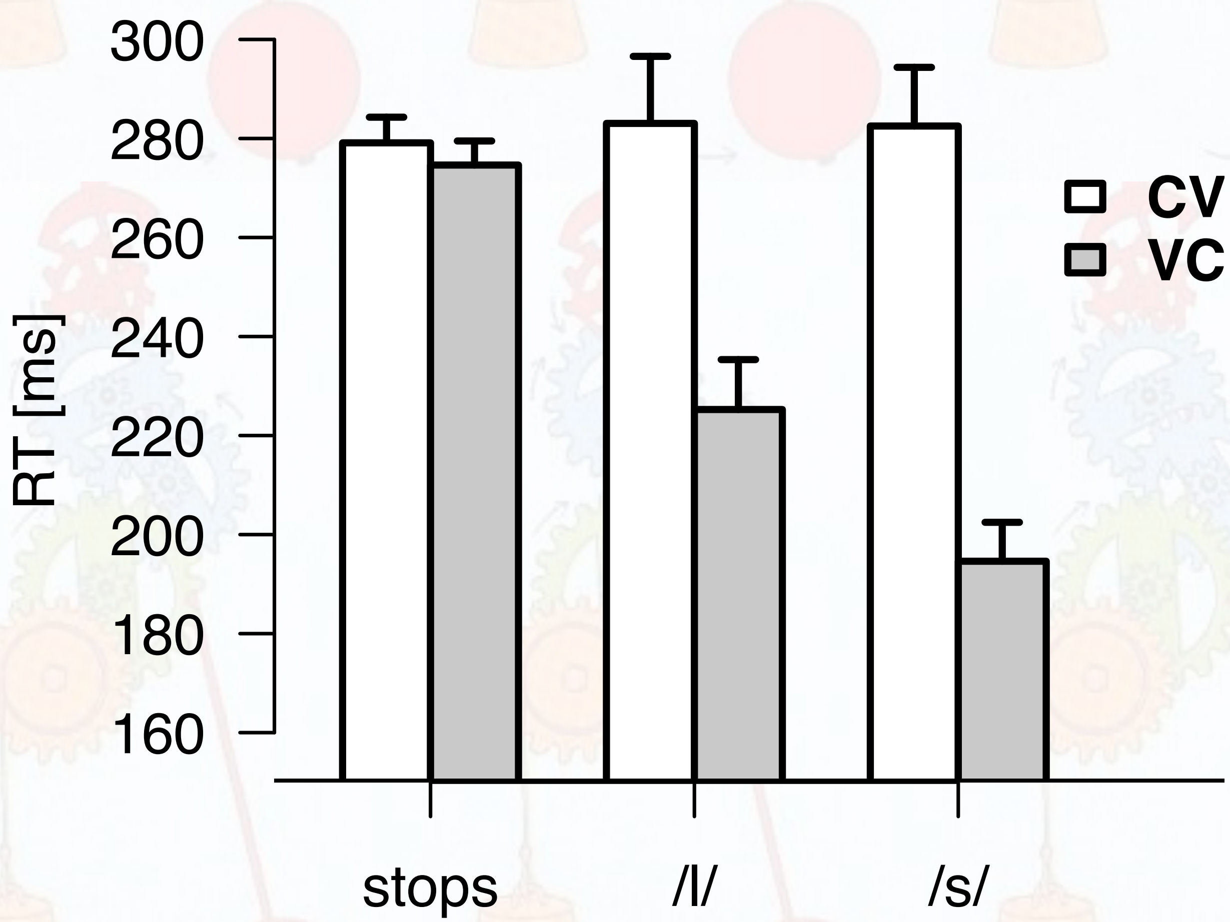
(Mooshammer et al, 2012)

- If settling of oscillators is part of production planning process, this predicts that CV syllables should be ready for triggering earlier than VC.
  - Task:
    - delayed naming
  - Measure:
    - Lag from 'go' signal to acoustic onset of response
  - Participants:
    - 20 American English
  - Materials:
    - VC, CV
    - V: /eI/ ('Kay'- 'ache')
      /i:/ ('Key'-'eke')
    - C: /p, t, k, s, l/



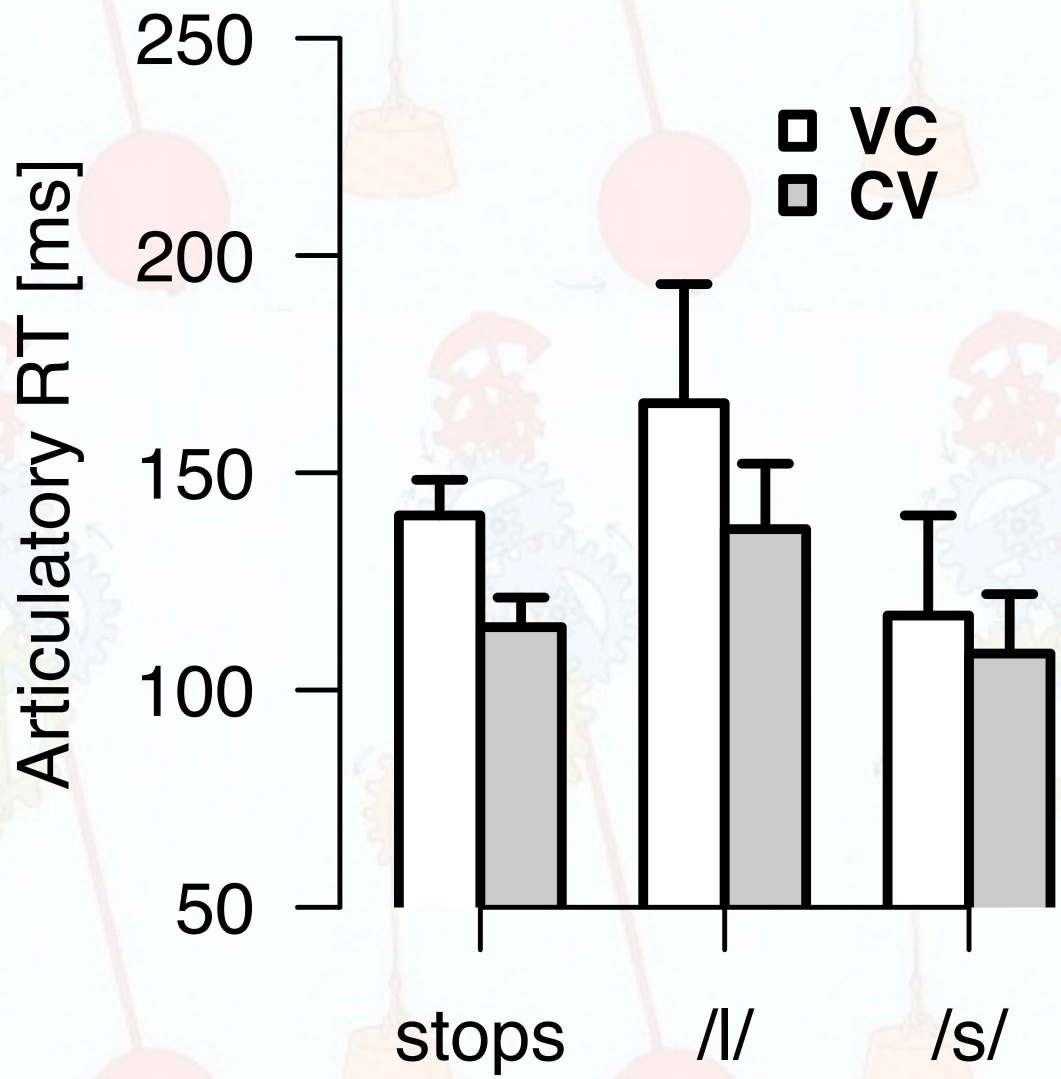
Results

- CV initiated significantly faster than VC



- Smaller effect for stops could be due to use of acoustic RT measure:
  - Acoustic onset for stops was measured at release burst.
  - Closure interval of initial voiceless stops (but not /s/ or /l/) is included in lag.

Articulatory Replication



- Method
  - EMA
  - Lag from 'go' signal to onset of constriction-directed movement for the initial gesture.
  - 4 participants
  - only /ei/ vowel context
- Results
  - CV significantly faster
  - no interaction with C

Acquisition of syllable structure

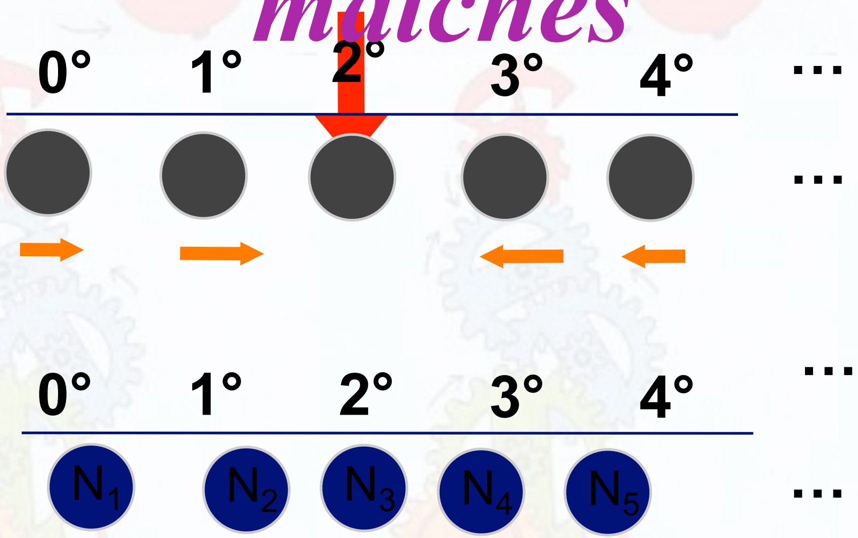
(Nam, Goldstein & Saltzman, 2009)

- Infants develop onsets (CV) before codas (VC) in all languages. (e.g.Vihman & Ferguson, 1987; Fikkert, 1994)
  - Lag in acquisition of codas is shorter in languages that make more frequent use of VC (Roark & Demuth 2000).
- Unlike single Cs, (intelligible) production of CC is observed earlier in codas than in onsets (e.g. Macken, 1977)
- These facts are all predicted by a model of a learning agent that includes both:
  - Greater accessibility in-phase mode
  - Attunement to C↔V phase in the ambient language

Model of phase learning: Representation & attunement

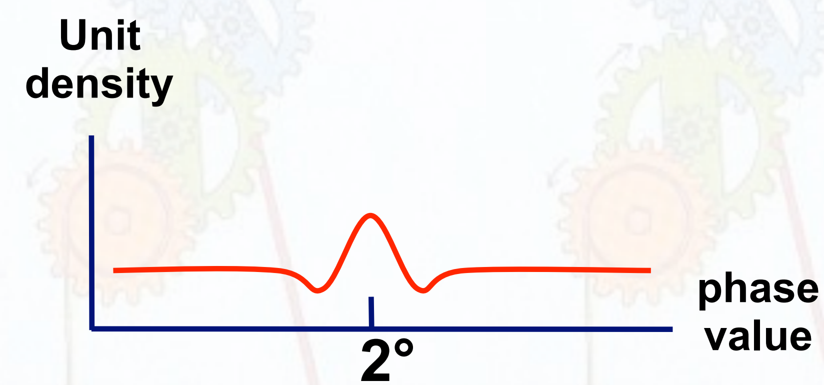
- "neural" units represent values of a phase continuum

Selected value 2º matches

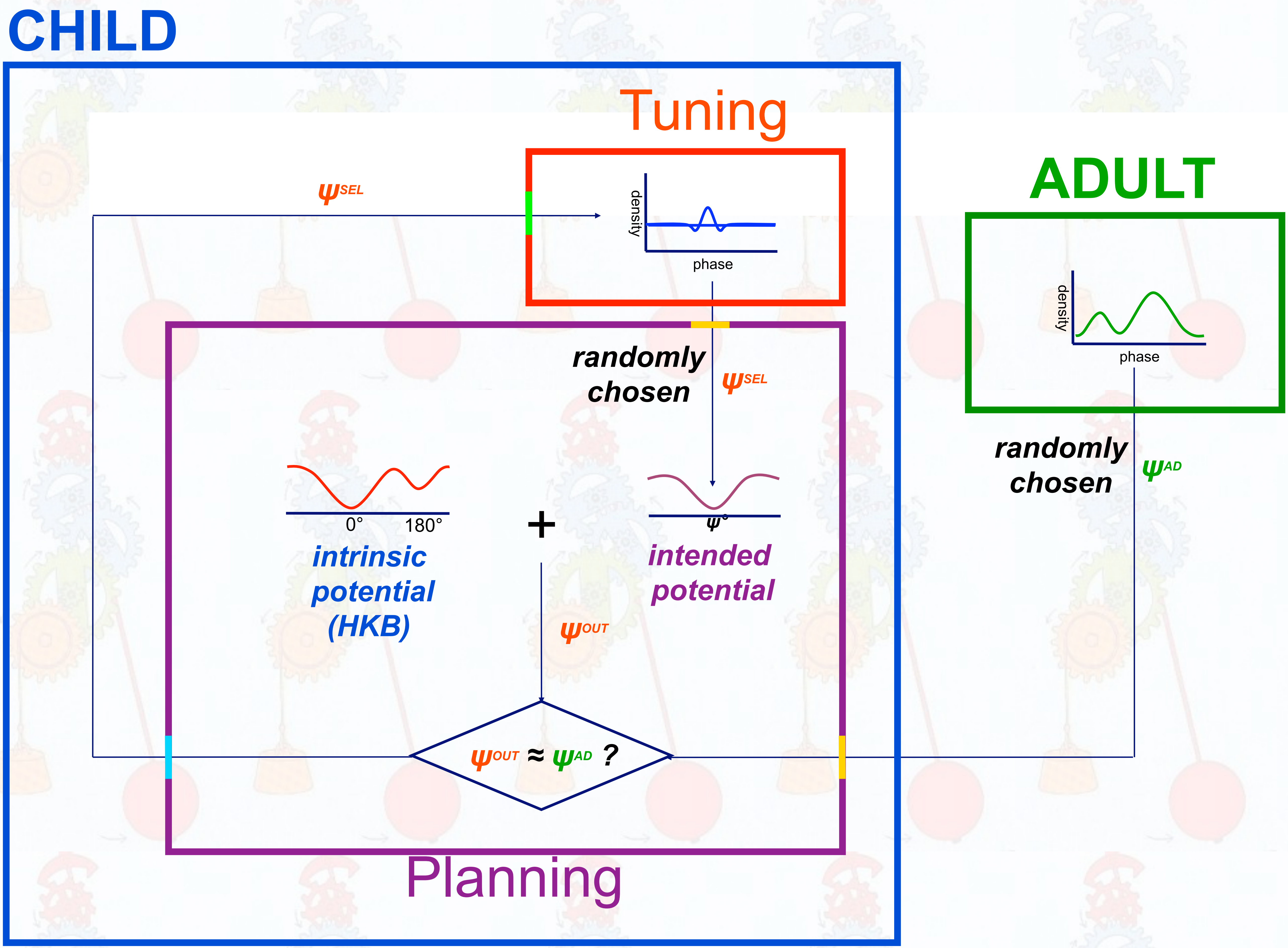


- neural units are slightly attracted to the phase value that has matched an adult utterance (*tuning or learning*)

- Units are ***selected*** at random from production.
- Distribution is flat at outset



- **Probability** of selecting a *matched* phase value **increases**

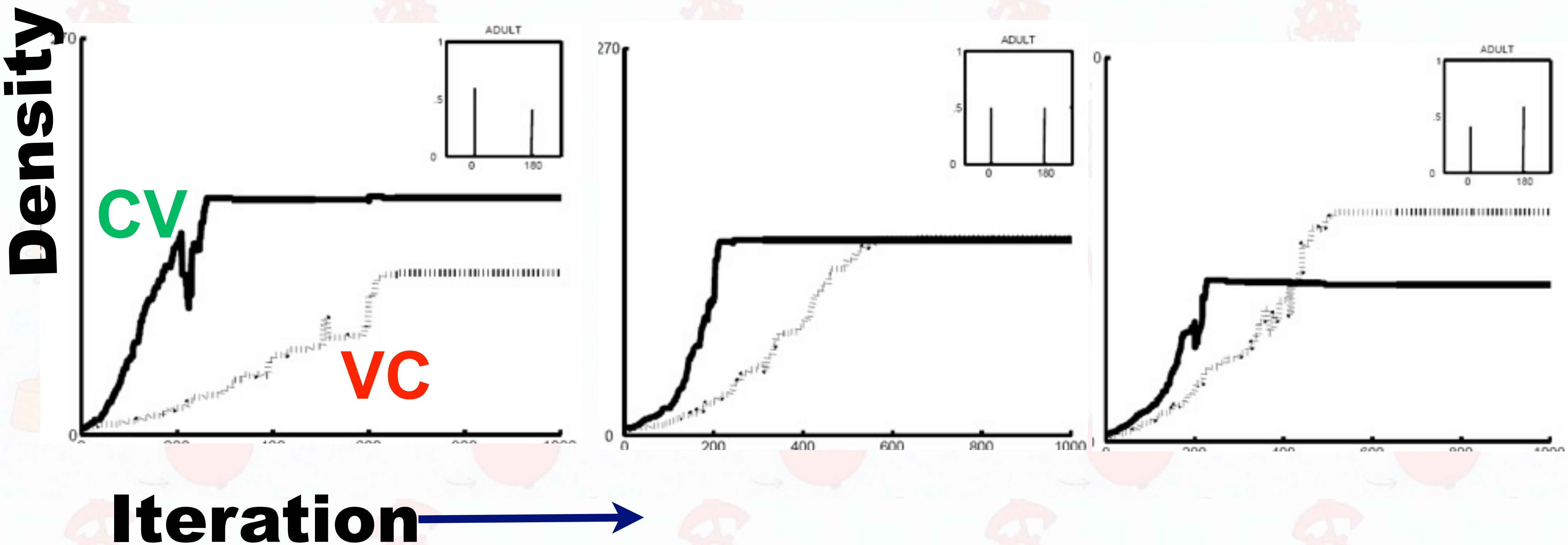

CHILD
Tuning
ψSEL
density
phase
ADULT
density
phase
randomly chosen
ψSEL
randomly chosen
ψAD
0°
180°
intrinsic potential (HKB)
+
ψ°
intended potential
ψOUT
ψOUT ≈ ψAD ?
Planning

Simulation Conditions

- Adult Frequency modes
  - CV>VC
  - CV=VC
  - CV<VC

Results

CV>VC CV=VC CV<VC

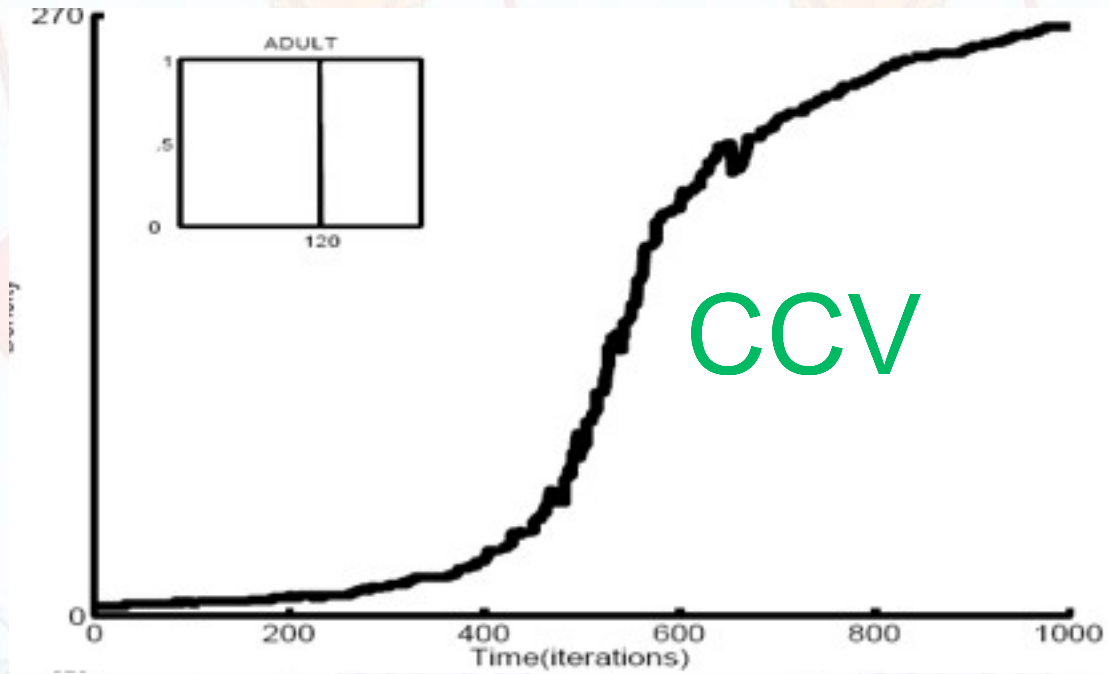


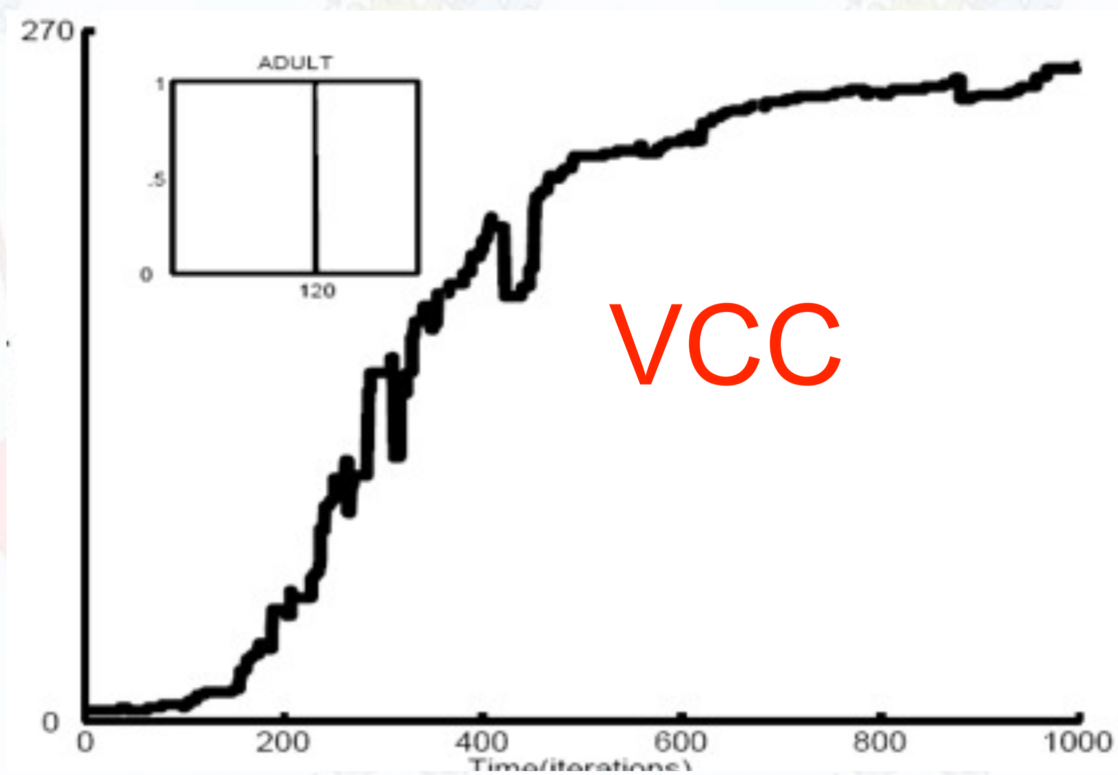
Paradox: Acquisition of CC

- In many languages, consonant clusters can be acquired in coda before onset (opposite result from single Cs).
    - English, Dutch, Spanish, German, Telegu
- This is predicted by phase learning model
    - Weaker V-C coupling in Coda makes it easier to learn to produce C-C sequencing

Extension of Phase Learning Model to Clusters

- Add 2nd C to learners experience.
- Coupling graph has to be learned:
  - C-C
  - C-V (or V-C)
- Development of C-C mode is faster in coda than in onset:
  - less strong competing synchronization





Graph Structure: Relative Phase Variability and the Connectivity Index

- Variability of steady-state relative phases is influenced by graph topology
  - Sensible, since the variability of relative phase between the i^{th} and j^{th} oscillator should reflect:
    - total number of unique paths between them (directly)
      – more paths enhance stability
    - length (number of links) of each of these paths (inversely)
      – short/direct paths will enhance stability more than longer paths
    - strength of each link along the paths (multiplicatively)
      – a weak link will diminish the strength of the entire path

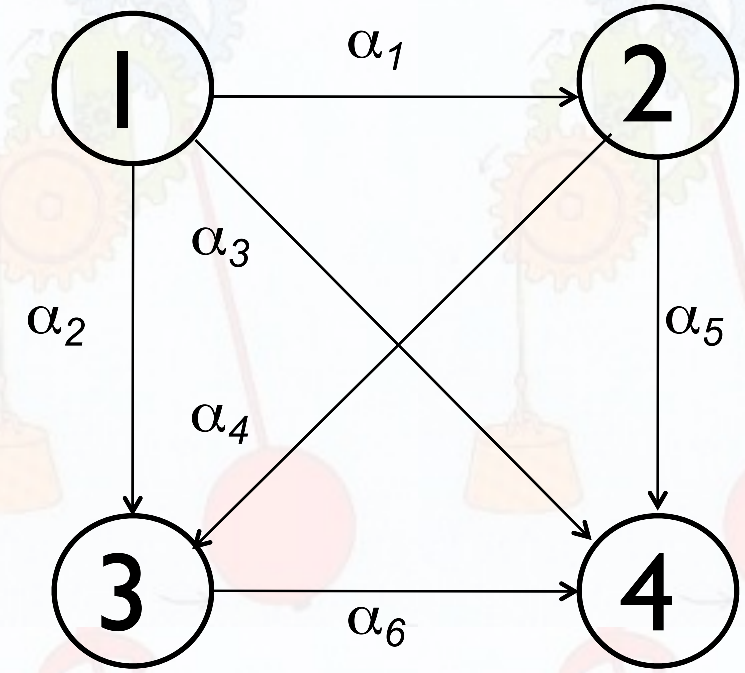
- Connectivity index, G_{ij}, for nodes i & j:

$$G_{ij} = \sum_{k=1}^{n_{ij}} \left(\frac{1}{p_{ijk}} \prod_{q=1}^{p_{ijk}} \alpha_{ijkq} \right) \quad (10)$$

n_{ij} = number of paths between nodes i & j;
p_{ijk} = length of k^{th} path between nodes i & j;
α_{ijkq} = strength of q^{th} link in k^{th} path between nodes i & j

Simulation: Standard Deviation and G_{ij}

- Tested G_{ij} on 4-node, graph with 100 simulation trials:
  - nonuniform coupling strengths (α_k)
    - varied randomly from 0-1
  - maximum of 2 deleted links ($\alpha_k = 0$) per trial
    - maintain a connected graph with at least 1 loop



- Simulation conditions
  - all relative phase targets = 0°
  - noise, $.05\xi_i(t)$, added to each component oscillator as acceleration forcing term
    - $\xi_i(t)$ = gaussian, zero mean, unit variance