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## Modeling sensory preference in speech motor planning

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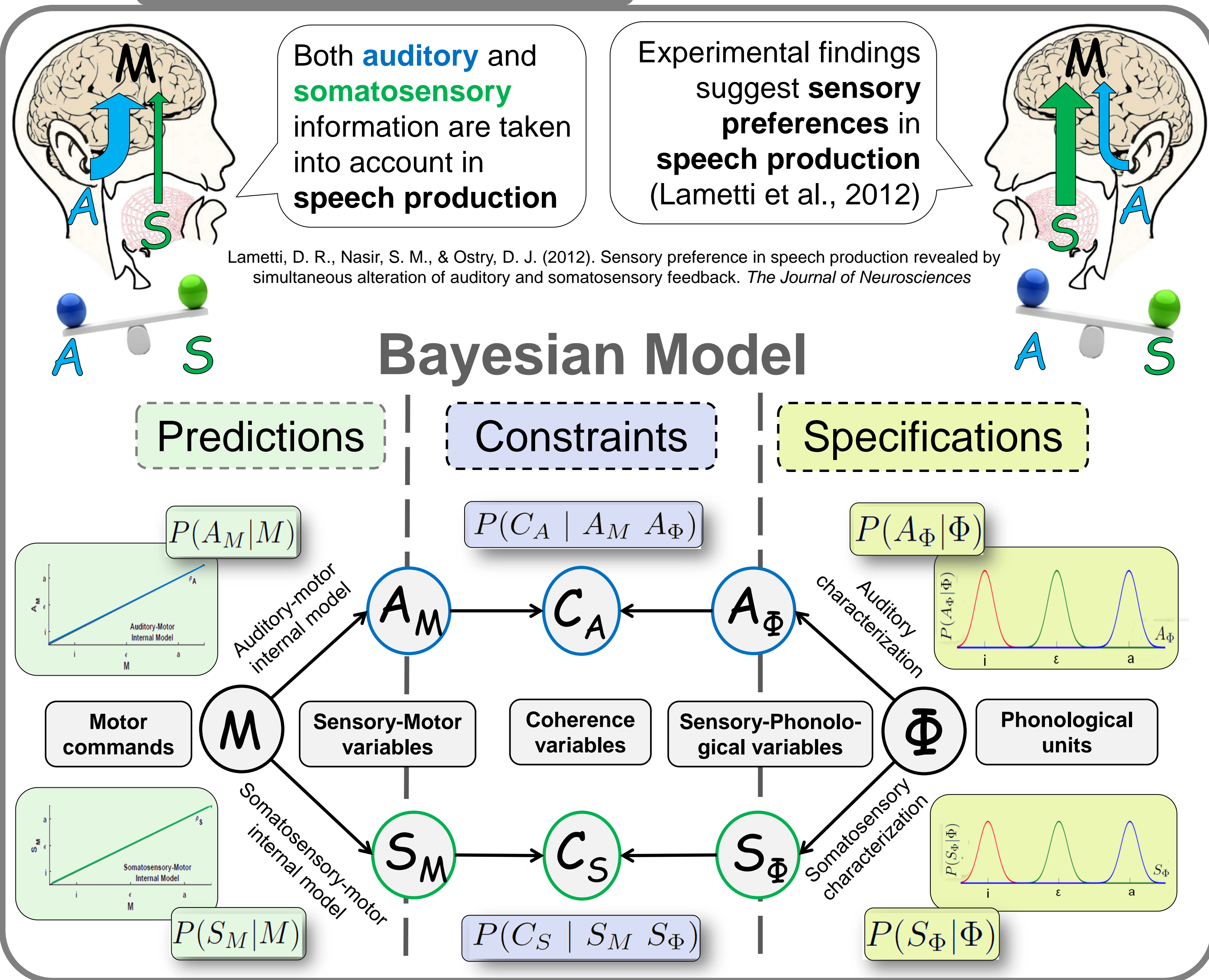


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## 1. Context & Framework



## 2. Assessing motor planning

Activation / Deactivation of 2 sensory constraints

3 Motor Planning Questions

Auditory pathway  $P(M | \Phi [C_A = 1] [C_S = 0])$

Somatosensory pathway  $P(M | \Phi [C_A = 0] [C_S = 1])$

Fusion of pathway  $P(M | \Phi [C_A = 1] [C_S = 1])$

Outcome of motor planning

$$P([M = m] | \Phi [C_A = 1] [C_S = 1]) \propto \Xi_A(\rho_A(m)) \Xi_S(\rho_S(m))$$

$$\Xi_A(\rho_A(m)) = \int_{A_\Phi} P(A_\Phi | \Phi) P([C_A = 1] | [A_M = \rho_A(m)] A_\Phi)$$

$$\Xi_S(\rho_S(m)) = \int_{S_\Phi} P(S_\Phi | \Phi) P([C_S = 1] | [S_M = \rho_S(m)] S_\Phi)$$

Sensory Characterizations → Activated Sensory Constraints

## 3. Weighting of sensory pathways

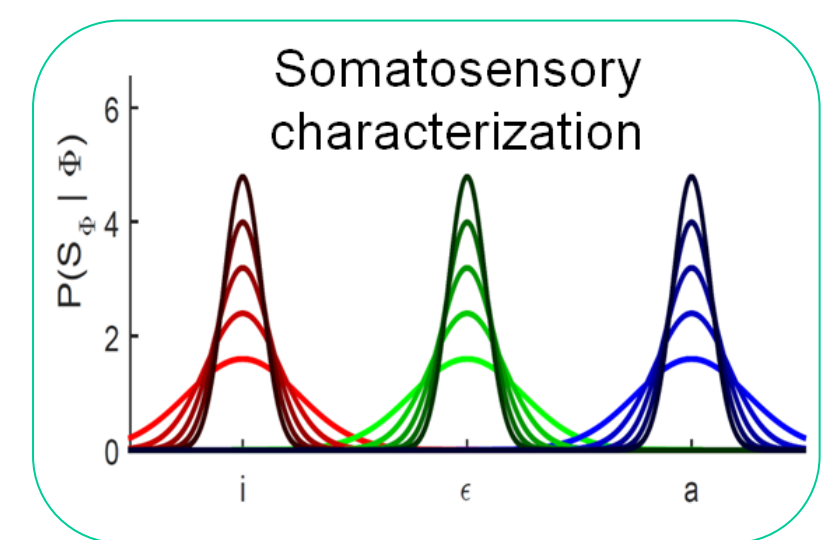
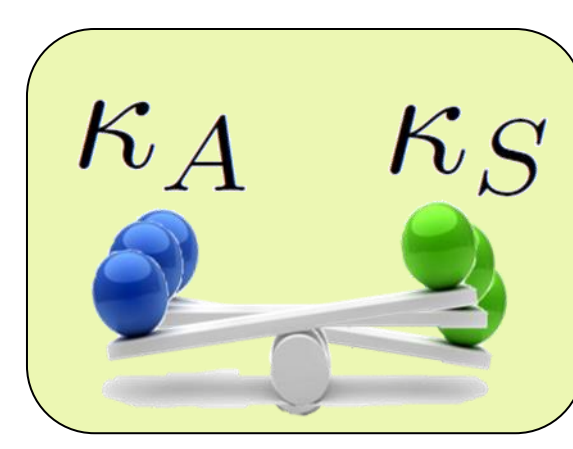
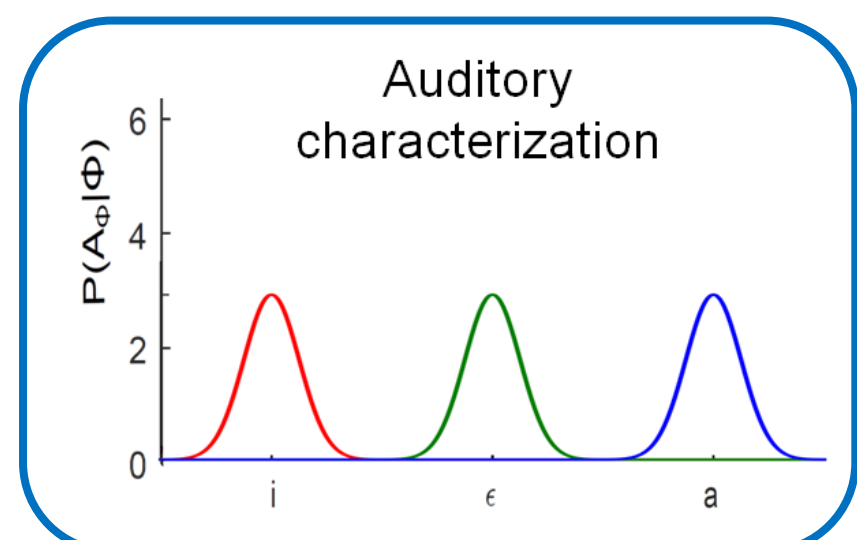
### 1st approach: Hard constraint

$$P([C_A = 1] | [A_M = a_m] [A_\Phi = a_\phi]) \propto \begin{cases} 1 & \text{if } a_m = a_\phi \\ 0 & \text{otherwise} \end{cases}$$

$$P([M = m] | \Phi [C_A = 1] [C_S = 1])$$

$$\propto P([A_\Phi = \rho_A(m)] | \Phi) \times P([S_\Phi = \rho_S(m)] | \Phi)$$

$$\propto \mathcal{N}(\rho_A(m); \mu_A^\Phi, \kappa_A, \Sigma_A^\Phi) \times \mathcal{N}(\rho_S(m); \mu_S^\Phi, \kappa_S, \Sigma_S^\Phi)$$



Outcome of motor planning

Weighting of pathways

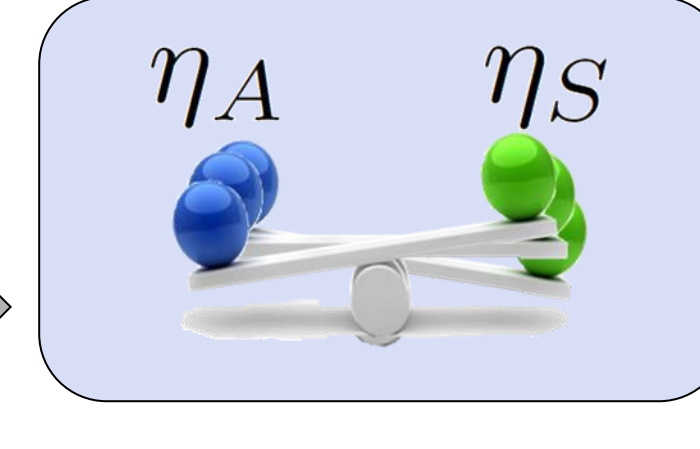
### 2nd approach: Soft constraint

$$P([C_A = 1] | [A_M = a_m] [A_\Phi = a_\phi]) \propto e^{-\frac{D_A(a_m, a_\phi)^2}{2\eta_A}}$$

$$P([M = m] | \Phi [C_A = 1] [C_S = 1])$$

$$\propto \int_a P([A_\Phi = a] | \Phi) e^{-\frac{D_A(a - \rho_A(m))^2}{2\eta_A}} \times \int_s P([S_\Phi = s] | \Phi) e^{-\frac{D_S(s - \rho_S(m))^2}{2\eta_S}}$$

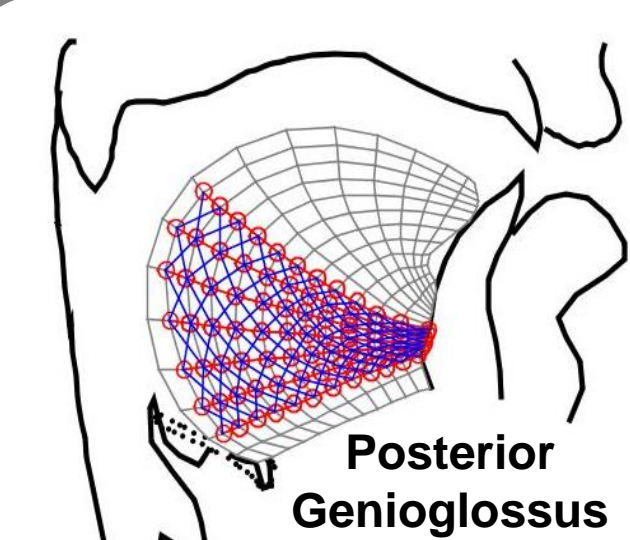
$$\propto \mathcal{N}(\rho_A(m); \mu_A^\Phi, \Sigma_A^\Phi + \eta_A) \times \mathcal{N}(\rho_S(m); \mu_S^\Phi, \Sigma_S^\Phi + \eta_S)$$



Equivalence of both approaches is exact in 1 dimension and approximate in higher dimensions.

## 4. Implementation: Adaptation to an auditory perturbation

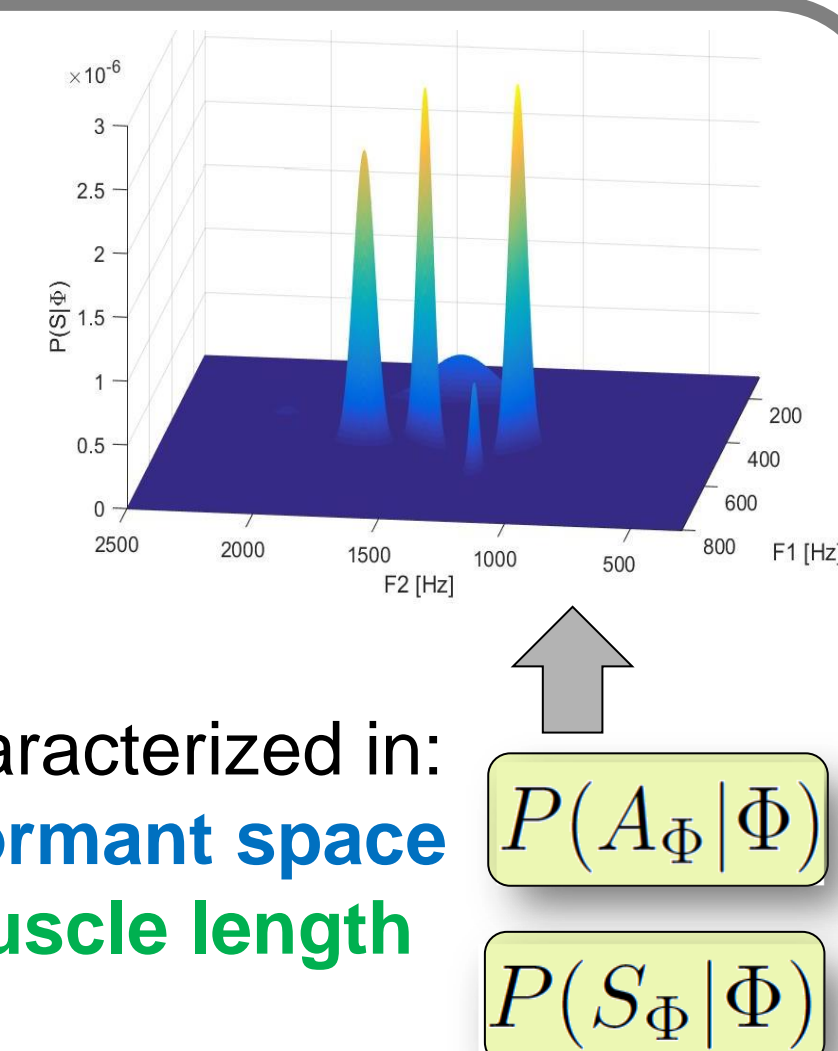
### Biomechanical model



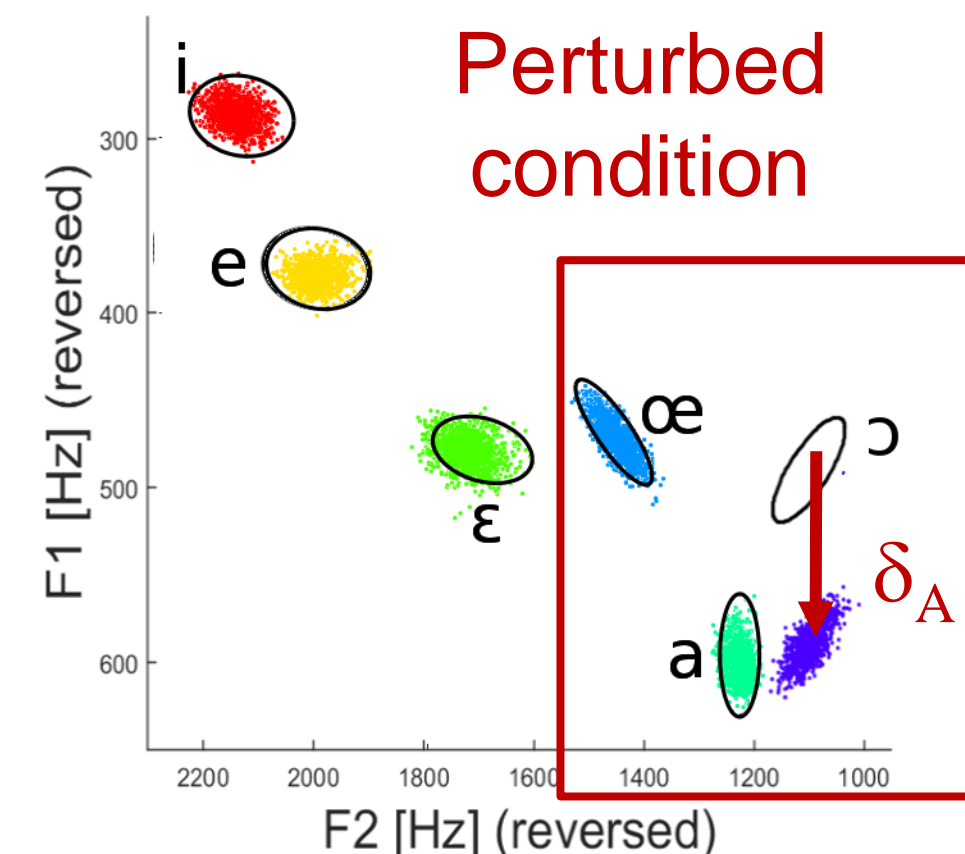
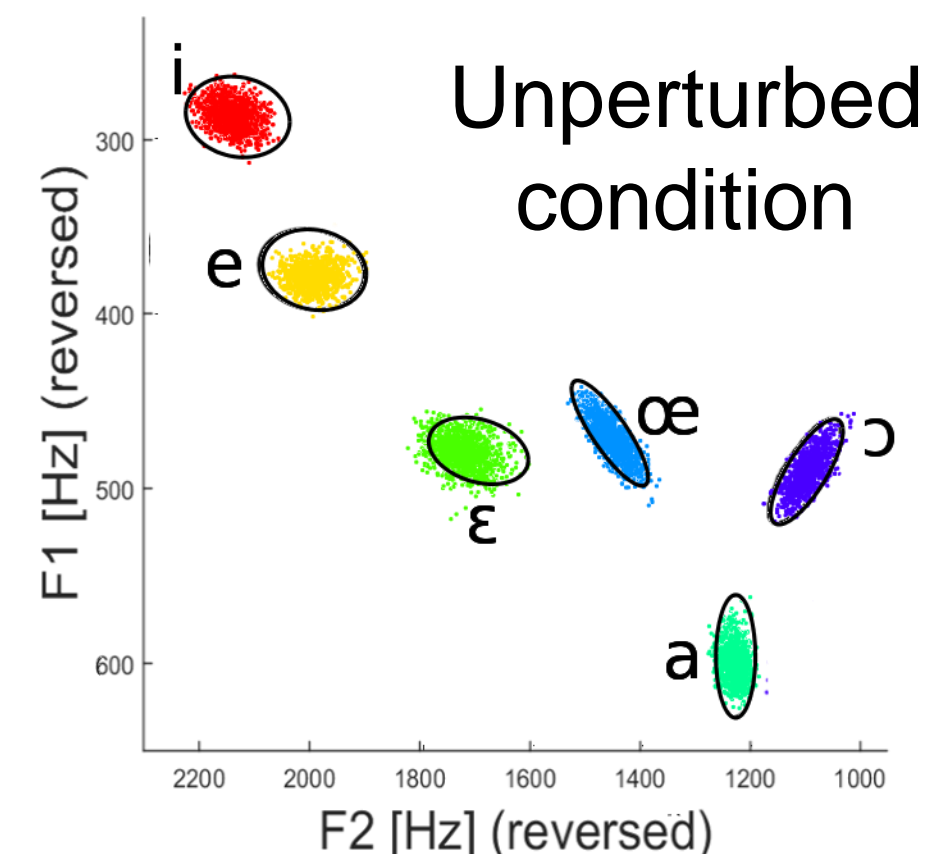
6 muscles activated via 6 λ parameters (Feldman, 1986)

Internal models: Radial Basis Functions  $\rho_A(m)$   $\rho_S(m)$

Vowels characterized in: 3-D Formant space, 6-D Muscle length space



### Outcome of productions in auditory space



### Result of motor adaptation

Update of auditory-motor internal model

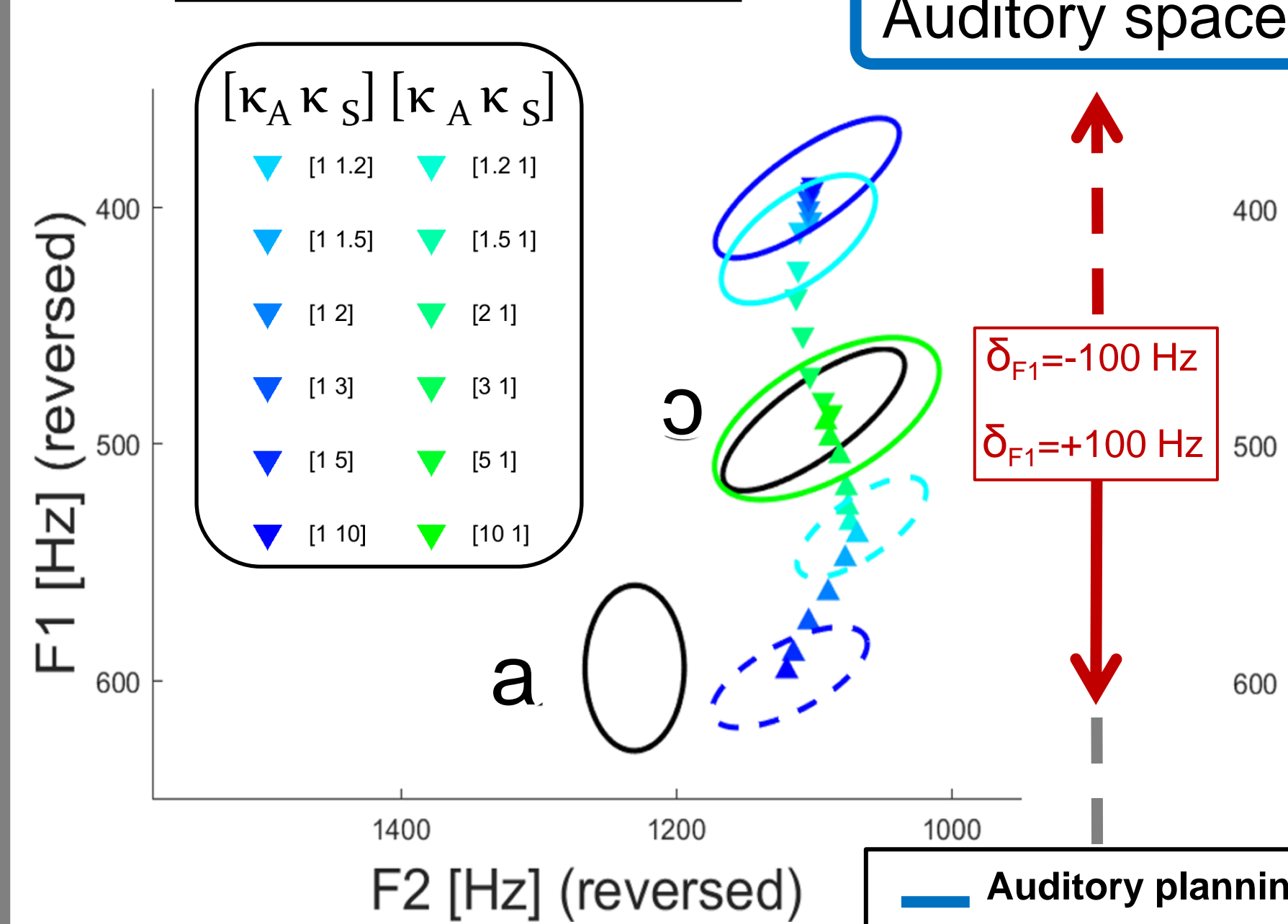
$$P(A_M|M)$$

$$\rho_A^{(a)}(m) = \rho_A^{(u)}(m) + \delta_A$$

Adapted = Unperturbed + Perturbation

## 5. Results

### 1st approach Hard constraint



### 2nd approach Soft constraint

