ARTphone Model Equations and Parameters

This document describes in detail the ARTphone model simulated in Pitt, Myung and Altieri (in press, *Psychonomic Bulletin & Review*). The schematic diagram of the model shown in the figure below is implemented via a system of differential equations. The basic model equations are derived from Grossberg, Boardman and Cohen (1997), to which the reader is directed for other details not described here.
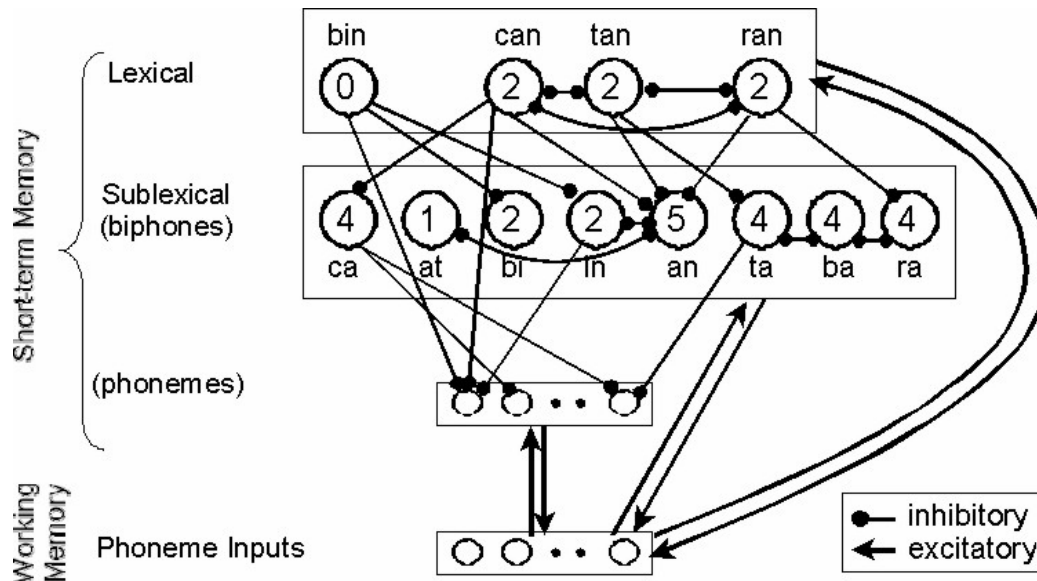

Figure 1. Schematic illustration of ARTPhone simulated in Pitt, Myung and Altieri (in press).

Items in Working Memory
Each working memory node receives a phoneme input pulse over a determined time interval

1. $\qquad I_j(t) = 0.1$ if $a_j < t < b_j$ and 0 otherwise

where the time interval (a_j, b_j) represents the duration of the phoneme input to the j-th working memory node, and 0.1 indicates the magnitude. Items in working memory interact with all items in short-term memory (phonemes, biphones, words) via bidirectional (bottom-up and top-down) excitatory connections between them. Let $x_j(t)$ be the activity at time t of the j-th phoneme node in working memory, and its activity is governed by the following differential equation

2. $\qquad dx_j(t)/dt = g\,[(\beta - x_j(t))(I_j(t) + \kappa\,\Sigma_k\,y_k(t)\,w_{kj}(t)) - \alpha x_j(t)]$

In this equation, $y_k(t)$ represents the activity of the k-th phoneme, bi-phone or word node in short-term memory, $w_{kj}(t)$ represents the activity of the top-down connection weight from y_k to x_j, and g, β, κ and α are positive constants.

Items in Short-term Memory
Items in short-term memory are 'category nodes' corresponding to phonemes, bi-phones or words. Let

$y_k(t)$ be the activity of the k-th node in a short-term memory layer, and its activity is governed by the equation below

3. $$dy_k(t)/dt = g\,[(\beta - y_k(t))(\Sigma_j\, m_j\, q_j(t)\, v_{jk}(t) - \delta y_k(t) - \varepsilon\Sigma_i\, y_i(t) - \eta\Sigma_i\, z_i(t)]$$

In the above equation, the thresholded signal $q_j(t)$ is defined as $q_j(t) = max(x_j(t) - \gamma,\, 0)$ for a given threshold parameter value γ, $v_{jk}(t)$ is the activity of the bottom-up connection weight from x_j to y_k, m_j is the parameter modulating the bottom-up processing to simulate the phonotactic probability effects, δ is the decay parameter, ε is the parameter representing the effects of lateral inhibition between chunks of the same size, η is the parameter representing the effects of top-down masking from larger chunks (e.g., words) to smaller chunks (e.g., biphones), and finally, $z_i(t)$ is the activity of a node representing a larger chunk that masks the activity of the smaller chuck node y_k.

Transmitter Dynamics of Top-down and Bottom-up Connections
The following equations describe the transmitter dynamics of the connection weights between layers

4. $$dw_{kj}(t)/dt = \varsigma(1 - w_{kj}(t)) - h(y_k(t))\, w_{kj}(t) \quad \text{(top-down transmitter)}$$

5. $$dv_{jk}(t)/dt = \varsigma(1 - v_{jk}(t)) - h(q_j(t))\, v_{jk}(t) \quad \text{(bottom-up transmitter)}$$

In each equation, ς represents the transmitter rate, and the transmitter inactivation rate function $h(x)$ is given by the equation $h(x) = \lambda x + \mu x^2$.

Model Parameters
The parameter values were derived from Grossberg et al (1997). The table below shows the values incorporated into our ARTphone model. Additions include the top-down modulating parameter κ, the phonotactic probability parameter m_j, and ε & η, the inhibition parameters.

Parameter	Description	Value
α	Decay	0.50
β	Maximum activation	1.0
κ	Top-down modulation	0.20
δ	Decay	0.28
γ	Threshold	0.10
ς	Transmitter rate	0.10
λ	Transmitter inactivation	0.10
μ	Transmitter inactivation	2.20
g	Gain control	1.10
ε	Lateral inhibition	(variable)
η	Masking inhibition	(variable)
m_j	Phonotactic probability effects[#]	(variable)

([#]: For the m_j values used in the simulations, see the appendix of Pitt, Myung & Altieri (in press).)

References

Grossberg, S., Boardman, I. & Cohen, M. (1997). Neural dynamics of variable-rate speech categorization. *Journal of Experimental Psychology: Human Perception and Performance, 23(2),* 481 – 503.

Pitt, M. A., Myung, J. I. & Altieri, N. (in press). Modeling the work recognition data of Vitevitch and Luce (1998): Is it ARTful? *Psychonomic Bulletin & Review*.