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

\[ I_j(t) = 0.1 \text{ if } a_j < t < b_j \text{ and } 0 \text{ otherwise} \]

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

\[ \frac{dx_j(t)}{dt} = g \left[ (\beta - x_j(t))(I_j(t) + \kappa \sum_k y_k(t) w_{kj}(t)) - \alpha x_j(t) \right] \]

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 \(g, \beta, \kappa\) and \(\alpha\) 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. \[
\frac{dy_k(t)}{dt} = g \left[ (\beta - y_k(t))(\sum_j m_j q_j(t) v_{jk}(t) - \delta y_k(t) - \varepsilon \sum_i y_i(t) - \eta \sum_i z_i(t) \right]
\]

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 $\gamma$, $v_{jk}(t)$ 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, $\delta$ is the decay parameter, $\varepsilon$ is the parameter representing the effects of lateral inhibition between chunks of the same size, $\eta$ 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 chunk 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. \[
\frac{dw_{kj}(t)}{dt} = \zeta (1 - w_{kj}(t)) - h(y_k(t)) w_{kj}(t) \quad \text{(top-down transmitter)}
\]

5. \[
\frac{dv_{jk}(t)}{dt} = \zeta (1 - v_{jk}(t)) - h(q_j(t)) v_{jk}(t) \quad \text{(bottom-up transmitter)}
\]

In each equation, $\zeta$ 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 $\kappa$, the phonotactic probability parameter $m_j$, and $\varepsilon$ & $\eta$, the inhibition parameters.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>$\alpha$</td>
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<td>$\beta$</td>
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<td>$\kappa$</td>
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<td>$\delta$</td>
<td>Decay</td>
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<td>$\lambda$</td>
<td>Transmitter inactivation</td>
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</tr>
<tr>
<td>$\mu$</td>
<td>Transmitter inactivation</td>
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<td>$g$</td>
<td>Gain control</td>
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<td>$\eta$</td>
<td>Masking inhibition</td>
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<tr>
<td>$m_j$</td>
<td>Phonotactic probability effects#</td>
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</tr>
</tbody>
</table>

(*: For the $m_j$ values used in the simulations, see the appendix of Pitt, Myung & Altieri (in press).)
References
503.

Pitt, M. A., Myung, J. I. & Altieri, N. (in press). Modeling the work recognition data of Vitevitch and