Developing a Model of Speech Production Using the Neural Engineering Framework and the Semantic Pointer Architecture

Bernd J. Kröger[1], Trevor Bekolay[2], Peter Blouw[2,3] & Terence C. Stewart[4]

[1]Department for Phoniatrics, Pedaudiology, and Communication Disorders, RWTH Aachen University, Aachen, Germany

[2]Applied Brain Research, Waterloo, ON, Canada

[3]Centre for Theoretical Neuroscience, University of Waterloo, Waterloo, ON, Canada

[4]National Research Council of Canada, University of Waterloo Collaboration Centre, Waterloo, ON, Canada

Introduction

Goal of paper: Developing a *biologically inspired* large-scale model of speech production using the *Neural Engineering Framework* (NEF; Eliasmith 2013) and the *Semantic Pointer architecture* (SPA; Stewart & Eliasmith 2014)

Focus: Introducing a concept for modeling different speaking rates

The model

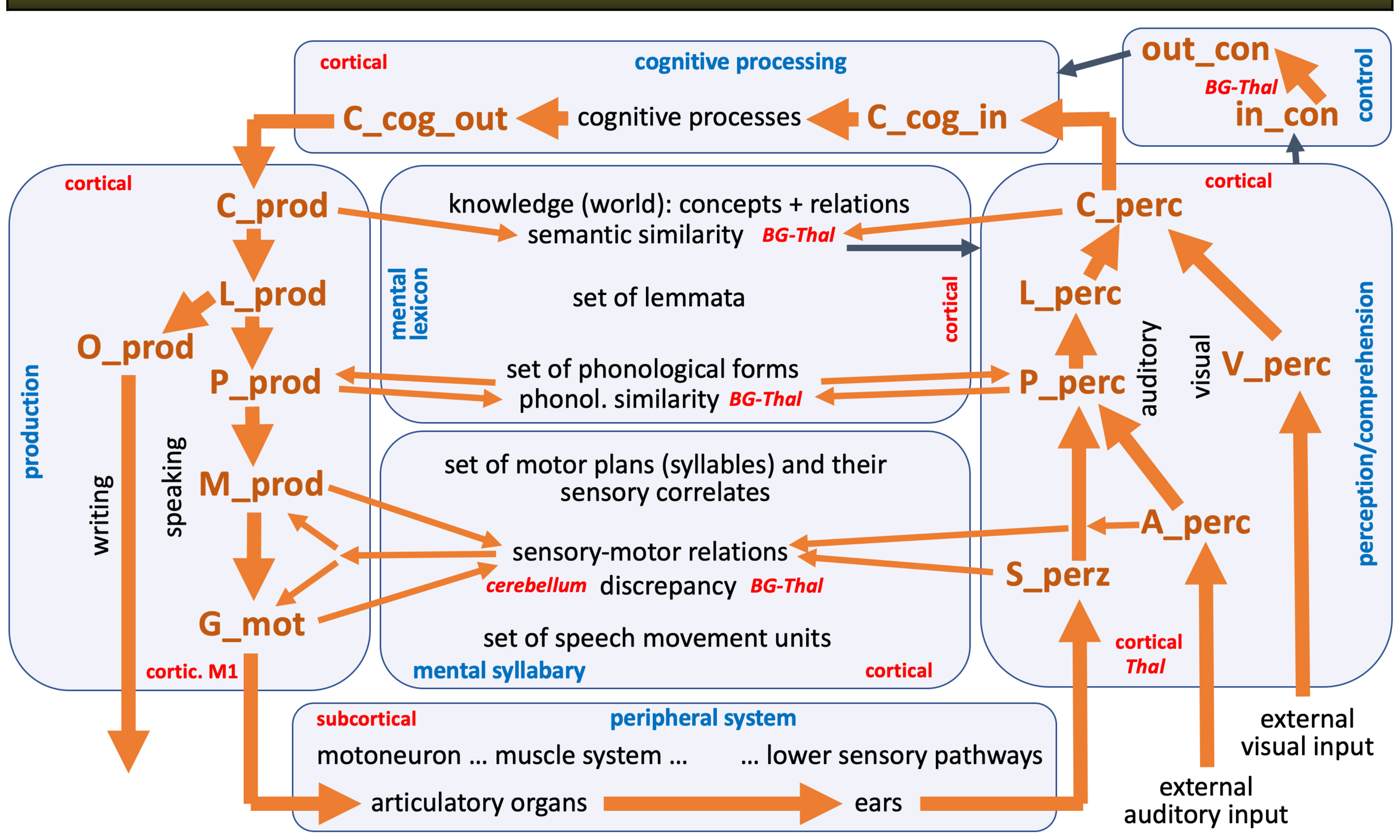

Fig. 1. The large-scale model (Kröger & Bekolay 2019, Kröger et al. 2020) comprising seven modules; neuron buffers for neural representations of concepts (C_), lemmata (L_), phonol. forms (P_), motor plans (M_), gestures (G_), somatosensory (S_), auditory (A_), visual (V_) and orthographic states (O_). Arrows indicate neural transformations.

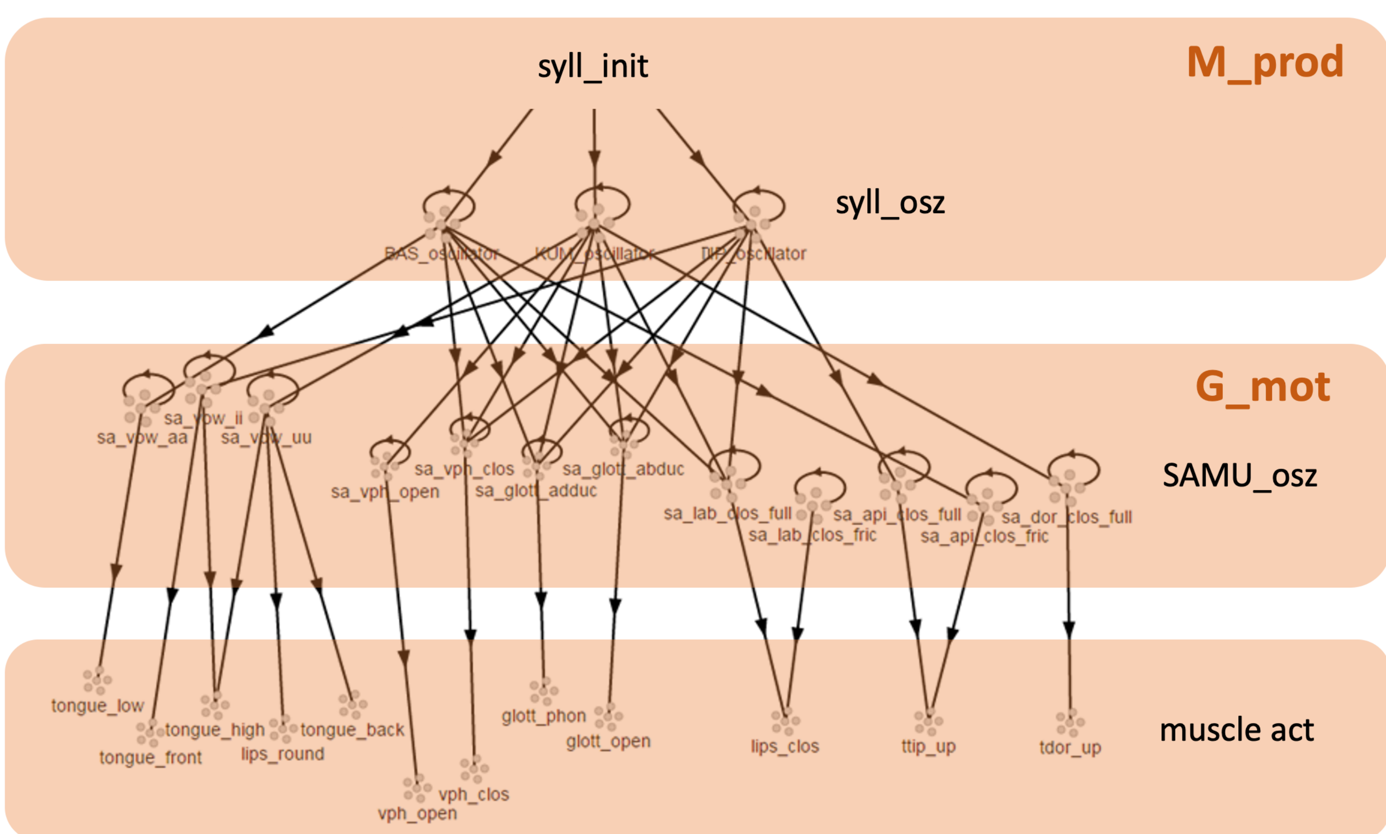

Fig. 2. The levels of the mental syllabary: motor plan level (syllable oscillators), SAMU level (gestures oscillators) and level for neural activation of muscle groups (neuron ensembles).

Simulation of a three-syllabic nonsense word

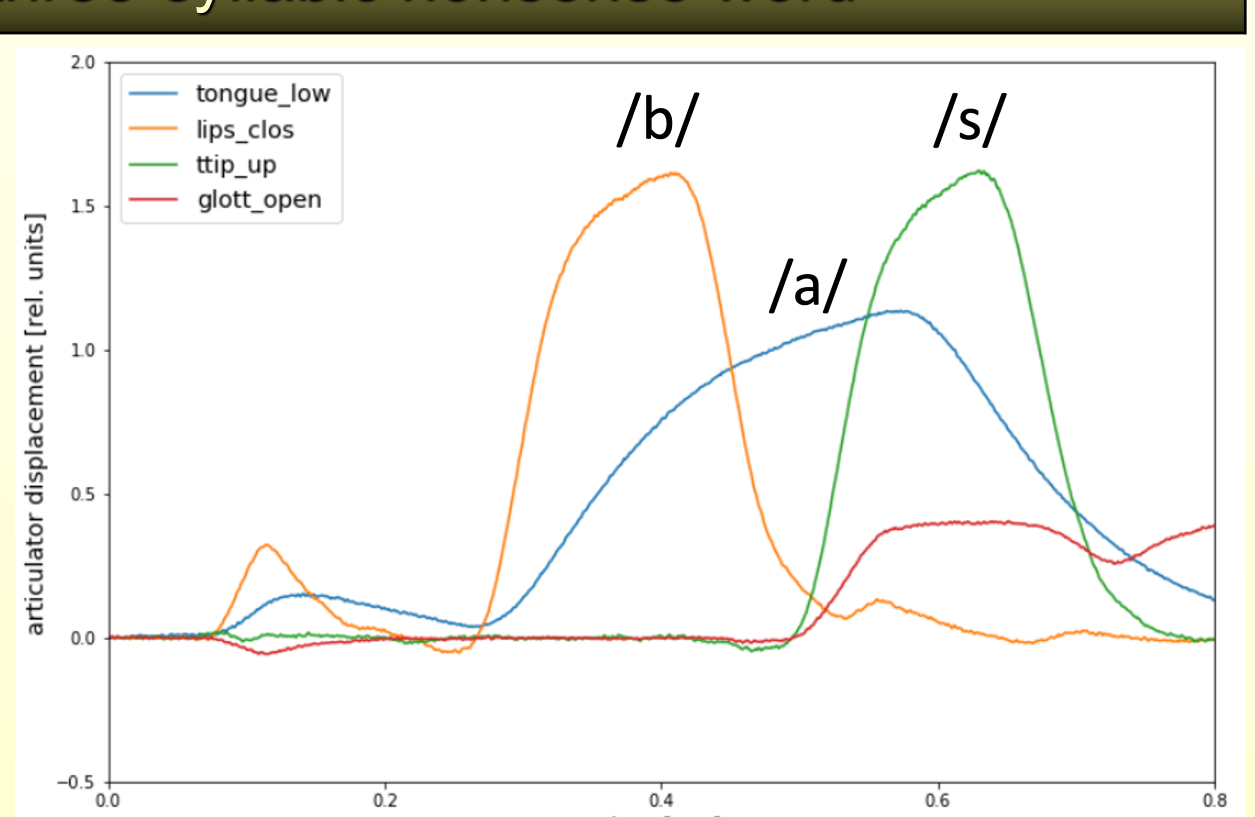

Fig. 3. resulting articulator trajectory for syllable /bas/ (first syllable of a three-syllabic nonsense word)

Simulations

Concept: (i) Syllable oscillators of *varying* frequency -> *speaking rate*
(ii) SAMU oscillators of *constant* frequency -> *vocalic vs. consonantal* gestures

- Video 1: simulation of three syllables
- Video 2: simulation of first syllable

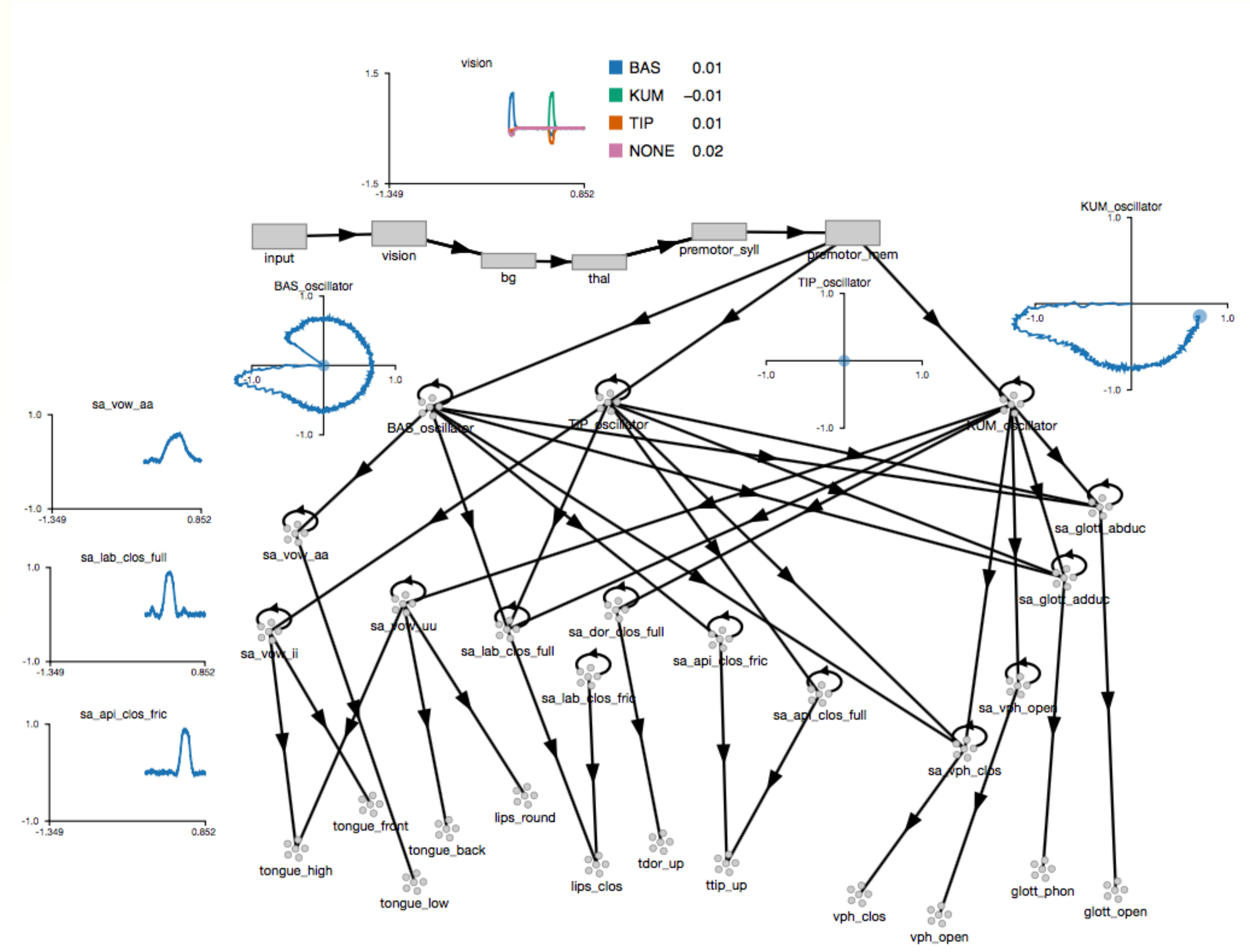

Fig. 4. simulation of the first syllable of a word: syllable oscillator triggering by premotor signals; syllable oscillator for /bas/; SAMU activation for vocalic and two consonantal gestures; for resulting articulator trajectories see Fig. 3.

Results of simulations: measuring articulator velocities

- Simulation of three-syllabic nonsense word: /baskumtip/ with:
- slow (f = 1.33 Hz), normal (f = 2 Hz) and fast (f = 3 Hz) speaking rate
- Measuring the resulting maximum articulator velocities (see Tab. 1) of four different types of SAMUs
- **Result:** Velocities vary from 0.7 to 1 (relative units; see Tab. 1) while speaking rate varies from 0.4 to 1 (relative units)
- **Interpretation:** Speaking with increasing rate is accomplished by increasing the temporal overlap of SAMUs while the *kinematic shape* of gestures remain stable (see Fujimura's 1992 *iceberg concept*)

abbrev.	movement direction & (dimension)		max vel. (percentage)		
SAMU		.	slow	normal	fast
aa_vow	lowering tongue body	(vertical)	100	100	100
li_clos	closing the lips	(vertical)	72	88	100
vph_open	lowering the velum	(vertical)	76	88	100
gl_open	opening the glottis.	(horizontal)	70	94	100

Tab. 1. Maximum movement velocities (rel. units) for different types of gestures

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More literature: see homepage of Bernd J. Kröger: www.speechtrainer.eu