Sequential selection and coordination in speech planning: a hybrid model

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complex sequential movements: example

A

brake pedal down  brake pedal up  gas pedal down

wheel to -x°  wheel to 0°
sequential timing

A

brake pedal down  brake pedal up  gas pedal down

wheel to -x°  wheel to 0°

[Diagram of car turning with annotations: A, brake pedal down, brake pedal up, gas pedal down, wheel to -x°, wheel to 0°]
coordinative timing

![Diagram showing timing steps: brake pedal down, brake pedal up, gas pedal down, wheel to -$x^\circ$, wheel to $0^\circ$.]
imprecise coordinative timing: disastrous consequences

A

brake pedal down  brake pedal up  gas pedal down

wheel to -x°  wheel to 0°

B

brake pedal down  brake pedal up  gas pedal down

wheel to -x°  wheel to 0°
errorful sequential timing: disastrous consequences
at a sufficiently abstract level timing is sequential
coordinative timing of onset consonants and vowels
sequential timing of vowels and coda consonants

A

/p/ onset

LA

TTy

TBy

/pa/

LA clo

PHAR nar

/spa/

LA clo

PHAR nar

TT nar

/ap/

PHAR nar

LA clo

/asp/

TT nar
coupled oscillators model: coordinative timing

**coupling graph**

**oscillator phases**

```
   movement
   trigger
```

**gestural scores**

```
/pa/
p→a
```

```
spa/
```

- **in-phase coupling**
- **anti-phase coupling**
coupled oscillators model: sequential timing

**Coupling Graph**

**Oscillator Phases**

**Gestural Scores**

```
coupling
graph

/pa/
p—a

movement
trigger

/apa/
ap

LA clo
PHAR nar

TT nar
LA clo
PHAR nar

in-phase coupling
anti-phase coupling

time
```
sequential selection with competitive queuing

- activation
- competition
- thresholded selection
- suppression
accounts for sequence length effects on RT

A

B

selection threshold

activation
time

unit 1
unit 2
unit 3
unit 4
can generate common error patterns

A

B

C

- unit 1
- unit 2
- unit 3
- unit 4

activation

time

selection threshold
**Problem:** how to explain the full range of empirical phenomena

- Competitive selection does not account for coordination of onset gestures
- Coupled oscillators do not *readily* account for sequence length/complexity effects
activation-spin model: combining coordination and selection

two dynamic variables: activation and spin for gestures, syllables, words

activation governs selection
spin governs coordination
**activation-spin model**: combining coordination and selection

*two dynamic variables:* **activation** and **spin**

for gestures, syllables, words

**activation** governs **selection**

**spin** governs **coordination**

**onset/coda asymmetry:**

onset gestures and vowel gestures:  
  *co-selected and coordinated*

CODA gestures:  
  *sequentially selected*
planning systems: **activation dynamics**

\[ \dot{x}_i = c_{x_i} \frac{-dV_i}{dx_i} + c_{\eta x_i} \eta_{x_i} \]
planning systems: activation dynamics

\[ V_i(v_i, w_i, x_i, y_i) = (c_d - w_i - v_i)\frac{x_i^2}{2} + y_i(e^{x_i} - x_i) \]

\[ - \frac{dV}{dx} = (-c_d + w_i + v_i)x_i + y_i(e^{x_i} - 1) \]
\[ V_i(v_i, w_i, x_i, y_i) = (c_d - w_i - v_i) \frac{x_i^2}{2} + y_i(e^{x_i} - x_i) \]
planning systems: *spin dynamics*

\[ \dot{\varphi}_i = \omega + c_\theta \sum_j - \frac{dV_{\varphi_{ij}}(\varphi_{ij})}{d\varphi_{ij}} + c_{\eta_\omega} \eta_\omega, \quad \theta = \text{mod}_{2\pi} \theta \]

\[ V_{\varphi_{ij}}(\varphi_{ij}) = - \alpha(i, j) \cos(\varphi_{ij}), \quad \varphi_{ij} = \theta_i - \theta_j \]
activation and spin coupling graphs

A

/CV/

/C CV/

/VC/

/VCC/

spin coupling

C

v

/v

C

C

C

C

B

/CV.CV/

/CV.CC

/CV # CVC/

activation coupling

σ

C

C

C

C

σ

C

C

C

C

σ

C

C

C

C

σ

C

C

C

C

σ

C

C

C

C
spin-coupling: $\varphi_{CV}$ equilibria

\[ \alpha_\sigma / |\alpha_g| \]

$\varphi_{CV}$ (rad)

$\Delta t_{CV}$ (ms)
dependence of RT on initial activation and activation gain

\[ \rightarrow \text{prepared vs. unprepared responses} \]
effects of utterance length and word complexity
Cued insertion task: dissociating selection and coordination

Fig. 6. Cued-insertion task: in the entrainment phase, the speaker repeats a context syllable to a periodic metronome tone; an insertion cue is given at a randomly determined time in the continuation phase.
acoustic measures reliably categorize onset-like and coda-like insertions
syllabification-as-onset more likely with earlier cue

(relative to upcoming vowel)
C-C timing in onset-syllabified tokens depends strongly on timing of insertion cue.