Gestural Scores as abstract representations

- Gestural scores represent activation intervals for dynamical systems controlling constrictions.
- They are abstract, in that they cannot be directly observed.
- Use heuristics for determining gestural activation, in two ways:
  1. From kinematics
     - Can be validated using model.
     - Heuristics work only when the overlapping gestures control distinct tract variables.
       • E.g. in ‘top cop’ timing of /t/ and /k/ can be directly inferred by heuristics, but not in ‘top part’ or ‘top fan’.
  2. From acoustics using analysis-by-synthesis with TaDA
     • Can be validated using kinematics.
1. **Structural Uniformity**
The patterns of gestural activations exhibited by sequences with the same syllable structure, but different C and V gestures are identical.
   - So we can generalize from sequences where the heuristics work, to those where they do not.

2. **Limited Gestural Interaction**
Overlapping gestures can interact only through:
   - shared articulators (case of distinct TVs)
   - blending of goal parameters (case of same TVs)
Gestural Scores from kinematics

- Active vs. passive changes in a TV.
  - Sources of passive changes
    - participation of one of a TV’s articulators in some other active gesture.
    - return of one of a TV’s articulators to a neutral posture, if it is not part of any active gestural regime.
Gestural scores from point movement data
/ˈpipəp/
/'pitap/
/p, t, k/
Gestural Scores from analysis-by-synthesis


**Pronunciation transcripts**
(e.g. K-AE-N for ‘can’)

- X-Ray microbeam database
- TADA+ HLsvn
- Synthetic database
- Time warping (LTW)
- X-ray microbeam Gestures

Related to forced phonetic alignment
Forced Phonetic Alignment

- Hidden Markov models of speech recognition
- Model of a word is sequence of acoustic states
- Within each state, there are different probabilities of output (observed) states.
- Based on observed output sequence, find the sequence of states that is the most likely one to give rise to that sequence.
- In speech recognition, states can be phonetic segments
- In forced alignment, the segments (and therefore state sequence) is known in advance.

  PROBLEM: find the optimal transition time between states
**HMM states**

\[ \begin{align*}
\text{URN 1} & : \\
\text{RED} & = b_1(1) \\
\text{BLUE} & = b_1(2) \\
\text{GREEN} & = b_1(3) \\
\text{YELLOW} & = b_1(4) \\
\vdots & \\
\text{ORANGE} & = b_1(M) \\
\end{align*} \]

\[ \begin{align*}
\text{URN 2} & : \\
\text{RED} & = b_2(1) \\
\text{BLUE} & = b_2(2) \\
\text{GREEN} & = b_2(3) \\
\text{YELLOW} & = b_2(4) \\
\vdots & \\
\text{ORANGE} & = b_2(M) \\
\end{align*} \]

\[ \begin{align*}
\text{URN N} & : \\
\text{RED} & = b_N(1) \\
\text{BLUE} & = b_N(2) \\
\text{GREEN} & = b_N(3) \\
\text{YELLOW} & = b_N(4) \\
\vdots & \\
\text{ORANGE} & = b_N(M) \\
\end{align*} \]

\[ O = \{ \text{GREEN, GREEN, BLUE, RED, YELLOW, RED, ..., BLUE} \} \]

**Fig. 3.** An \( N \)-state urn and ball model which illustrates the general case of a discrete symbol HMM.
Penn Forced Aligner

- http://fave.ling.upenn.edu/FAAValign.html
- Pre-trained models for English segments (and other languages)
Gestural Scores from analysis-by-synthesis


**Pronunciation transcripts**
(e.g. K-AE-N for ‘can’)

- X-Ray microbeam database
- TADA+ HLsvn
- Synthetic database
- Time warping (LTW)
- X-ray microbeam Gestures

Related to forced phonetic alignment
Gestural Pattern Vectors

• Small slices can be coded as *gestural pattern vectors* (GPV) (Zhuang, Nam et al 2008).

• which constricting organs are active?

• what constriction types?

• Analysis of corpus of TaDA Model output for English requires <200 distinct pattern
Gestural Pattern Vectors

- If TaDA output and XRMB output share the same GPV sequence...
- Then the problem is one of finding the boundaries between GPV intervals.
- Use phonetic forced alignment to bootstrap.
- Regular (approx) relation between phone boundaries and gesture onsets.
Evaluation by DTW score

Iter 1
Iter 2

\( \text{Iter}_{\text{opt}} \quad G_{\text{opt}} \quad D_{\text{opt}} \)

\( G_1 \quad G_2 \)

time warping
TV correlation after alignment

- LA (ULy ~ LLy) and TTCD (minimum distance of T1 to palate) can be reliably obtained from XRMB.

![Graph showing TV correlation](image)

**TABLE V.** Correlation between the annotated TVs and the TVs derived from the measured flesh-point information of XRMB database.

<table>
<thead>
<tr>
<th>TVs</th>
<th>Consonants</th>
<th>Vowels</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA</td>
<td>0.715</td>
<td>0.686</td>
</tr>
<tr>
<td>TTCL</td>
<td>0.291</td>
<td>—</td>
</tr>
<tr>
<td>TCD</td>
<td>0.596</td>
<td>—</td>
</tr>
<tr>
<td>TBCL</td>
<td>0.510</td>
<td>0.391</td>
</tr>
<tr>
<td>TBCD</td>
<td>0.579</td>
<td>0.587</td>
</tr>
<tr>
<td>Avg</td>
<td>0.538</td>
<td>0.555</td>
</tr>
</tbody>
</table>
Gestural scores and language-specific phonetic detail

Traditional approach: Implementation Rules

- Take categorical phonological feature specification and map them in a language particular fashion onto time-varying quantitative parameters.

NOT necessary:

- Alternative model of phonological structure (the gestural structure and gestural score) in which both categorical units (dynamical equations) and time-varying properties co-exist (solution of equations).

NOT sufficient:

- Superficially unrelated qualitative alternations can emerge from language-particular generalizations governing the structure of the gestural score.
Language differences in temporal overlap of consonant gestures

Across languages
Languages that are hypothesized to differ in consonant gesture overlap are predicted to exhibit multiple corresponding differences in articulatory and acoustic consequences.
Catford: Open vs. Close Transition of $C_1C_2$ in Languages

<table>
<thead>
<tr>
<th>Seq Type</th>
<th>Open</th>
<th>Close</th>
</tr>
</thead>
<tbody>
<tr>
<td>heterorganic:</td>
<td>complete release of $C_1$</td>
<td>overlapping constrictions: no release of $C_1$</td>
</tr>
<tr>
<td>e.g. [pk]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>adjacent:</td>
<td>no mutual accommodation (no assimilation)</td>
<td>mutual accommodation (assimilation)</td>
</tr>
<tr>
<td>e.g. [sj]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>homorganic:</td>
<td>release of $C_1$</td>
<td>no release of $C_1$</td>
</tr>
<tr>
<td>e.g. [pp]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Overlap and Open vs. Close Transition

- Open transition results from no overlap of gestures in CC sequence.
- Close transition results from some degree of overlap in CC sequence.
- Detailed consequences as a function of type of sequence do not have to be stipulated in grammar as they follow from the effect of overlap on that sequence type, under the hypothesis that overlap is the same across types.
Evidence for language-specific patterns of overlap of CC

- Examine sequences with distinct tract variables in English and Russian.
English: Overlap of consonant gestures

"top cop"

TTCD

TBCD

LA

Time

100 ms
Russian: NO overlap

/tap kap/

Time

100 ms

TTCD

TBCD

LA

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Consequences for heterorganic sequences

- English: frequently no release, but variable.
- Russian: always released (Zsiga, 2000)
Consequences for adjacent sequences

- Overlap results in articulatory interaction.
- English: partial assimilation/accommodation
- Russian: no assimilation
Palatalization of /s/

“miss. you”

Overlap changes fricative acoustics

Zsiga (1995)
Palatalization of /s/

Figure 20.5. Change in contact patterns over time, subject 1. Electrodes shown in black were activated in at least eight of ten repetitions, those in gray, in seven of ten repetitions.
Palatalization of /s/

Figure 20.6. Templates from underlying /s/, /ʃ/, and /ɻ/ overlaid on the patterns for s+you and derived /ʃ/ at -3 frames.
Simulation in TaDA

(a) “miss. you”

(b) “missyou”
"miss # you"

% /m/
'LA' 0 0 9 0 -2 8 1 JA=8, UH=5, LH=1 1 1
'LA' 0 9 13 0 11 8 1 JA=8, UH=5, LH=1 1 1
'VEL' 0 0 9 0 0.2 8 1 NA=1 1 1

% /ih/
'TBCL' 0 0 30 0 95 3 1 JA=10, CL=1, CA=1 1 1
'TBCD' 0 0 30 0 8 3 1 JA=1, CL=1, CA=1 1 1

% /s/
'TTCD' 0 25 34 0 1.2 10 1 JA=640, CL=32, CA=32, TL=1, TA=1 10 0.1
'TTCL' 0 25 34 0 56 10 1 JA=640, CL=32, CA=32, TL=1, TA=1 1 1
'TBCD' 0 25 34 0 10 8 1 JA=10, CL=1, CA=1 10 0.1
'TBCL' 0 25 34 0 110 8 1 JA=10, CL=1, CA=1 10 0.1

'VEL' 0 25 34 0 -0.1 8 1 NA=1 0 0
'GLO' 0 28 37 0 0.4 16 1 GW=1 0 0

'TTCD' 0 33 37 0 11 8 1 JA=512, CL=512, CA=512, TL=1, TA=1 1 1
'TTCL' 0 33 37 0 24 8 1 JA=512, CL=512, CA=512, TL=1, TA=1 1 1

% /j/
'TBCL' 0 33 63 0 125 4 1 JA=10, CL=1, CA=1 1 1
'TBCD' 0 33 63 0 4 4 1 JA=1, CL=1, CA=1 1 1

% /u/
'TBCL' 0 33 63 0 125 4 1 JA=10, CL=1, CA=1 1 1
'TBCD' 0 33 63 0 4 4 1 JA=1, CL=1, CA=1 1 1
'LA' 0 33 63 0 5 4 1 JA=1, UH=5, LH=1 1 1
'LP' 0 33 63 0 12 4 1 LX=1 1 1

% /w/
'LA' 0 58 67 0 1 8 1 JA=8, UH=5, LH=1 1 1
'LA' 0 67 70 0 11 8 1 JA=8, UH=5, LH=1 1 1

"miss you"

% /m/
'LA' 0 0 9 0 -2 8 1 JA=8, UH=5, LH=1 100 0.01
'LA' 0 9 13 0 11 8 1 JA=8, UH=5, LH=1 1 1
'VEL' 0 0 9 0 0.2 8 1 NA=1 1 1

% /ih/
'TBCL' 0 0 30 0 95 3 1 JA=10, CL=1, CA=1 1 1
'TBCD' 0 0 30 0 8 3 1 JA=1, CL=1, CA=1 1 1

% /s/
'TTCD' 0 25 34 0 1.2 10 1 JA=640, CL=32, CA=32, TL=1, TA=1 10 0.1
'TTCL' 0 25 34 0 56 10 1 JA=640, CL=32, CA=32, TL=1, TA=1 1 1
'TBCD' 0 25 34 0 10 8 1 JA=10, CL=1, CA=1 10 0.1
'TBCL' 0 25 34 0 110 8 1 JA=10, CL=1, CA=1 10 0.1

'VEL' 0 25 34 0 -0.1 8 1 NA=1 0 0
'GLO' 0 28 37 0 0.4 16 1 GW=1 0 0

'TTCD' 0 33 37 0 11 8 1 JA=512, CL=512, CA=512, TL=1, TA=1 1 1
'TTCL' 0 33 37 0 24 8 1 JA=512, CL=512, CA=512, TL=1, TA=1 1 1

% /j/
'TBCL' 0 33 63 0 125 4 1 JA=10, CL=1, CA=1 100 0.01
'TBCD' 0 33 63 0 4 4 1 JA=1, CL=1, CA=1 100 0.01

% /u/
'TBCL' 0 33 63 0 125 4 1 JA=10, CL=1, CA=1 1 1
'TBCD' 0 33 63 0 4 4 1 JA=1, CL=1, CA=1 1 1
'LA' 0 33 63 0 5 4 1 JA=1, UH=5, LH=1 1 1
'LP' 0 33 63 0 12 4 1 LX=1 1 1

% /w/
'LA' 0 58 67 0 1 8 1 JA=8, UH=5, LH=1 1 1
'LA' 0 67 70 0 11 8 1 JA=8, UH=5, LH=1 1 1

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Consequences for homorganic sequences

- English and Russian both show no release why?
- Overlap of $C_1$ and $C_2$ in TADA
  - same relative timing specified for
    - “top cop”
    - “top pop”
  - release after “top” in “top cop” but not “top pop”.
  - Why?
- English shows considerable shortening of [CC] compared to [C], and Russian shows less
Homorganic sequence

“bad. day.”

“badday.”
Overlap Ratio (Zsiga)

- Technique for estimating overlap from acoustic durations.
- \[
\text{Duration of } C_1 C_2 \text{ in } V C_1 C_2 V \div \text{Duration of } C_1 \text{ in } V C_1 V + \text{Duration of } C_2 \text{ in } V C_2 V
\]
Zsiga (2000)

% Released

Overlap ratio

English: light bars; Russian: dark bars

Consistent in English
Overlap and Release in English vs. Russian

- English has more overlap (shortening), lower percent released.
- Different coordination constraint
- Homorganic clusters in English have same overlap ratio as heterorganic, but different % release. Why?
- English keeps overlap constant, release varies by combination.
- Russian varies overlap, but almost all are released. English and Russian /pt/ have about the same overlap but different % released? How is that possible?
Place order effects

- With high degrees of overlap
  - front-back sequence --> more audible release
  - back-front sequence --> less audible release
- English uses the same overlap regardless of place order, so % release > for front-back
- Russian manipulates overlap (to ensure release?), so overlap > for front-back
Zsiga (2000)

% Released

Overlap ratio

English: light bars; Russian: dark bars

Consistent in English

(a) % Released

(b) Overlap ratio
Phases of gesture’s dynamics
Critical Damping

- Undamped

Effective Target achievement: 240°

b = 2, k = 1

b = 0, k = 1
Zsiga: Alignment Constraints

- ALIGN phases defined by natural frequency of gesture dynamics.

- English:
  - ALIGN (C1, [240-270°], C2, 240°)

- Russian (heterorganic):
  - ALIGN (C1, [260-320°], C2, 240°)
Palatalization in English & Russian

English

Figure 4. (a) Mean centroid values at beginning, middle, and end of the fricative for /s/, /ʃ/, and /s + ʃ/ in English. (b) A spectrogram of the phrase “press you” spoken by subject E4.

Russian

Figure 5. (a) Mean centroid values at beginning, middle, and end of the fricative for /s/, /ʃ/, and /s + ʃ/ in Russian. (b) A spectrogram of the phrase “pas jejo” from speaker R4.
Figure 6.
Variation in the amount of palatalization in English. All spectrograms are from subject E4. (a) No assimilation. The phrase "miss yesterday". (b) Some assimilation. The phrase "press uranium". (c) Complete assimilation. The phrase "Boris Yeltsin".
Relation between stop overlap and palatalization

Table VII. Rankings of the 10 subjects on the three experimental measures

<table>
<thead>
<tr>
<th>Fewest released</th>
<th>Lowest duration ratio</th>
<th>Most /s + j/ tokens palatalized</th>
</tr>
</thead>
<tbody>
<tr>
<td>E2 4%</td>
<td>E4 0.751</td>
<td>E2 100%</td>
</tr>
<tr>
<td>E4 8%</td>
<td>E2 0.769</td>
<td>E4 63%</td>
</tr>
<tr>
<td>E3 13%</td>
<td>E3 0.77</td>
<td>E1 63%</td>
</tr>
<tr>
<td>E5 26%</td>
<td>E5 0.78</td>
<td>E5 13%</td>
</tr>
<tr>
<td>R3 30%</td>
<td>R5 0.798</td>
<td>R1 13% (0%?)</td>
</tr>
<tr>
<td>R1 38%</td>
<td>E1 0.847</td>
<td>E3 0%</td>
</tr>
<tr>
<td>E1 40%</td>
<td>R4 0.856</td>
<td>R2 0%</td>
</tr>
<tr>
<td>R2 47%</td>
<td>R3 0.939</td>
<td>R3 0%</td>
</tr>
<tr>
<td>R5 56%</td>
<td>R1 0.985</td>
<td>R4 0%</td>
</tr>
<tr>
<td>R4 62%</td>
<td>R2 1.041</td>
<td>R5 0%</td>
</tr>
</tbody>
</table>

Most released | Greatest duration ratio | Fewest /s + j/ tokens palatalized

Overlap can account for both release properties and palatalization
Generality of Place order effects

- More overlap in front-back than back-front shows up in many languages.
- Why?
Harmonic clusters in Georgian (Chitoran et al., 2002)

- Overlap relations deeper in grammar?
- Harmonic clusters (front-to-back)
  - must agree in glottal state (aspirated, ejective, neither)
  - more overlap?
- Non-harmonic (back-to-front)
  - may disagree, but C2 may not be aspirated or ejective
  - less overlap
- Analysis
  - Only one glottal gesture (abduction, adduction) coordinated with C1.
  - When Cs overlap, glottal gesture extend over C2.
  - So, not really deeper in grammar.
## Overlap in Georgian (Chitoran et al, 2002)

<table>
<thead>
<tr>
<th>Consonants</th>
<th>Word-initial sequences</th>
<th>Word-internal sequences</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>C1</strong></td>
<td><strong>C2</strong></td>
<td></td>
</tr>
<tr>
<td><strong>front-to-back</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>g</td>
<td>bgera</td>
</tr>
<tr>
<td>p\textsuperscript{h}</td>
<td>t\textsuperscript{h}</td>
<td>p\textsuperscript{h}t\textsuperscript{h}ila</td>
</tr>
<tr>
<td>d</td>
<td>g</td>
<td>dg-eb-a</td>
</tr>
<tr>
<td><strong>back-to-front</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>b</td>
<td>g-ber-av-s</td>
</tr>
<tr>
<td>t\textsuperscript{h}</td>
<td>b</td>
<td>t\textsuperscript{h}b-eb-a</td>
</tr>
<tr>
<td>g</td>
<td>d</td>
<td>gd-eb-a</td>
</tr>
</tbody>
</table>
Analyzed Articulatory Events

Utterance: ‘...dgebra...’
How early does $C_2$ onset occur within the constriction interval of $C_1$?

Order of Place of Articulation

back to front

front to back

% delay within $C_1$ constriction interval

more overlap ...................... less overlap
STOP-STOP sequences: Interpretation of order of place effect

- If C2 constriction is anterior to C1 in the vocal tract, C1 release may be completely hidden acoustically, unless the gestures are sufficiently separated.

  e.g., [kt]  Less overlap favored:
  TT
  TD

- If C2 constriction is posterior to C1, some acoustic information will still be present at C1 release, even given a substantial amount of overlap.

  e.g., [tk]  More overlap ok:
  TT
  TD
HYPOTHESIS: STOPS AND LIQUIDS

If the order of place effect is due to perceptual recoverability only, combinations of stops and liquids should not show this effect.

• Overlap in [pl] front-to-back, and [kl] back-to-front, should be comparable

  The acoustic release of the stop is never completely hidden, regardless of the amount of overlap

• Overlap in [rk] front-to-back, and [rb] back-to-front, should be comparable

  The acoustic release of the liquid is not necessary to its perception
Overlap measure: ONSET LAG

Time between onset of C1 gesture and onset of C2 gesture

\[\ldots \text{q'wa}^{th}\text{beb}\ldots\] in

\[\text{sit'q'wa}^{th}\text{beba}\]
Results – Lag in stop-stop sequences

Speaker GP

Initial

Medial

Speaker JJ

Front-back

Back-front

Longer lag (less overlap) word-initially and in back to front sequences

p < .0001

Longer lag in back to front sequences

p < .0001
## Experiment 2: Stop-liquid sequences

<table>
<thead>
<tr>
<th>$C_1C_2$</th>
<th>Front to back (labial-coronal)</th>
<th>Back to front (dorsal-coronal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pʰletʰ-a</td>
<td>‘to tear up’</td>
<td>k’lantS’-i ‘claw’</td>
</tr>
<tr>
<td>p’laZ-i</td>
<td>‘beach’</td>
<td>k’leb-a ‘reducing’</td>
</tr>
<tr>
<td>p’reś-a</td>
<td>‘press’</td>
<td>k’reb-a ‘to meet’</td>
</tr>
<tr>
<td>p’rasa</td>
<td>‘leek’</td>
<td>k’repʰ-a ‘picking’</td>
</tr>
<tr>
<td>braz-i</td>
<td>‘anger’</td>
<td>k’rav-i ‘lamb’</td>
</tr>
</tbody>
</table>

- 7 repetitions, randomized, in carrier phrase

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Experiment 3: Liquid-stop sequences

<table>
<thead>
<tr>
<th>$C_1C_2$</th>
<th>Front to back (coronal-dorsal)</th>
<th>Back to front (coronal-labial)</th>
</tr>
</thead>
<tbody>
<tr>
<td>rk$^h$-eb-i</td>
<td>‘horn’ pl.</td>
<td>rben-a</td>
</tr>
<tr>
<td>rk$'$al-i</td>
<td>‘arc’</td>
<td>rbew-a</td>
</tr>
</tbody>
</table>

• 7 repetitions, randomized, in carrier phrase
Place order effect

- French shows similar stop-liquids effects as Georgian in stop liquid clusters (/pl/, /kl/).
- Why?
- Relation to labial-coronal bias in infant’s first words (MacNeilage, 2010).
- Bias found in repetition of sequences (Rochet-Capellan & Schwartz, 2007): [tapa]-->[pata]
- Relation to jaw? Lancia & Fuchs, 2011
Gestural Invariance Hypothesis (B&G, 1990)

- Phonetic or phonological alternations in casual speaking style can the result from:
  - invariant gestural parameters (target, stiffness?)
  - quantitative changes in the gestural score (overlap, activation interval)

- Under certain conditions, these can also result in sound changes.
Phonetic alternations due to changes in gestural score

- **Quantitative** changes in gestural score can give rise to **qualitative** changes in output (as transcribed).

- **Sources** of quantitative change:
  - Prosody (accent, boundaries)
  - Speaking rate
  - Other?

- **Types** of quantitative change:
  - Activation interval (producing undershoot)
  - Overlap (obsuring the articulatory and acoustic output of a gesture)
Examples

- /t/-/d/ deletion
- Place assimilation of coronals
Example: /t/ “deletion” from Tiede et al. 2004.

Due of change of speaking style, the degree of overlap between the gestures altered, but the gestural controls remain the same → Robustness of Gestures
Modeling prosodic variation: “told before”

- Phrase was generated automatically by TaDA/HLsyn, then boundary gesture slowing effects were added.
- [d] release emerged automatically with slowing, due to decrease in overlap of Tongue Tip and Lip Gestures.

TaDA:

- No [d] audible
- [d] release

Talker 12

- Only 2/38 Transcribers hear boundary

Talker 15

- 11/38 Transcribers hear boundary

Apertures:
- Tongue Tip
- Lip

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Assimilation of Coronals

- In English, final coronals can assimilate to following labials and dorsals.
- This results from both temporal reduction of final /t/ and overlap

"MY tot puddles"

![Graph showing tongue tip height and lip aperture over time.](Image)
"MY top tuddles"

The diagram shows the movement of the tongue tip and lip aperture over time, with labels for tongue tip height and lip aperture. The time is measured in milliseconds (ms) with values of 200, 400, and 600. The tongue tip height is indicated with a 30 mm measurement. The lip aperture shows 'closed' and 'high' positions.
Assimilation of /n/

“can # be”

VELUM: WIDE
LIPS: LAB STOP
TT: ALV ST
TB: VEL ST WIDE PAL NAR
GLOTTIS: WIDE

“can be”

VELUM: WIDE
LIPS: LAB STOP
TT: ALV ST
TB: VEL ST ALV ST PAL NAR
GLOTTIS: WIDE

Sunday, November 2, 14
can be
## Monitoring Experiment
(Suprenant & Goldstein, 1998)

<table>
<thead>
<tr>
<th>TARGET</th>
<th>PRESENT</th>
<th>ABSENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>“t”</td>
<td><em>overlapped</em></td>
<td><em>top puddles</em></td>
</tr>
<tr>
<td></td>
<td><em>nonoverlapped</em></td>
<td><em>top huddles</em></td>
</tr>
<tr>
<td>“p”</td>
<td><em>overlapped</em></td>
<td><em>top tuttles</em></td>
</tr>
<tr>
<td></td>
<td><em>nonoverlapped</em></td>
<td><em>top huddles</em></td>
</tr>
</tbody>
</table>
Results

Experiment 1: Two Word Phrases (e.g., "tot puddles")

Experiment 2: Single Word Only (e.g., "tot")
Correlations

Experiment 2: Single Words

Detection Rate vs. Lip - TT Lag (ms)

Detection Rate = .77

Detection Rate vs. LA change during closure (mm)

Detection Rate = -.60