Introduction

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  - We can’t directly access the grammar, so we rely on (our perception of) the speech sounds
- However, getting from grammar to perception requires multiple intermediate mappings
  - ...each of which is non-linear

![Diagram of the relationship between grammar, acoustics, and perception]

- Grammar (mental object)
- Acoustics (physical object)
- Perception (mental object)

- Gestures
  - Quantal effects (Stevens, 1972; Stevens & Keyser 2010)

- Effects from perceiver’s grammar (surveyed in Hume & Johnson, 2001)
Introduction

- A perceived sound process may not actually be a grammatical / phonological process
- Instead, it may have been introduced by one of the non-linear mappings that intervene between grammar and perception
This talk

- Introduce two vowel insertion processes in Turkish
- Propose that one is a gestural / perceptual phenomenon
  - Not grammatical / phonological
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- Introduce two vowel insertion processes in Turkish
- Propose that one is a gestural / perceptual phenomenon
  - Not grammatical / phonological
- Support this claim with results from a production study (ultrasound + acoustic)
Turkish vowel insertion

- **Coda cluster repair**
  - /cebr/ → [cebı̈r] ‘algebra’
  - /sabr/ → [sabı̈r] ‘patience’
  - /ömr/ → [ömür] ‘life’
  - /burn/ → [burun] ‘nose’

Examples from: Clements & Sezer, 1982; Turkish Electronic Living Lexicon (Inkelas et al, 2000)
Turkish vowel insertion

• Onset cluster repair
  - /prens/ → [pirens] ‘prince’
  - /branda/ → [bıransa] ‘canvas’
  - /brüt/ → [bürüt] ‘gross’
  - /prova/ → [purova] ‘test’

Examples from: Clements & Sezer, 1982; Turkish Electronic Living Lexicon (Inkelas et al, 2000)
Turkish vowel insertion

- Coda cluster repair
  - Affects only clusters that violate SSP
  - Obligatory, written
  - Target for stress
  - Consistently harmonic

- Onset cluster repair
  - Affects clusters that don’t violate SSP
  - Optional, unwritten
    - Clements & Sezer, 1982; Yıldız, 2010
  - Irrelevant to stress
  - Variably harmonic
    - Yavaş, 1980; Clements & Sezer, 1982; Kaun, 1999; original TELL study
Turkish vowel insertion

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Coda and onset cluster repair happen at different points in the mapping from grammar to perception

Clements & Sezer, 1982; Yıldız, 2010

Original TELL study

Yavaş, 1980; Clements & Sezer, 1982; Kaun, 1999
Turkish vowel insertion

- Coda repair is **epenthesi**s
  - Phonological, categorical
Turkish vowel insertion

- Coda repair is **epenthesis**
  - Phonological, categorical
  - Epenthetic vowel has a gestural target
Turkish vowel insertion

- Onset repair is **intrusion**
  - Phonetic, gradient
  - Vowel percept results from the timing relations of adjacent gestures
Turkish vowel insertion

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  - Vowel percept results from the timing relations of adjacent gestures
    - No added gestural target Hall, 2006; Davidson & Stone, 2003
Turkish vowel insertion

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  – Phonetic, gradient
  
  – Vowel percept results from the timing relations of adjacent gestures
    
    • No added gestural target  
      
      Hall, 2006; Davidson & Stone, 2003
Method

• Production experiment with ultrasound
  – modeled on Davidson & Stone 2003

• Design: Target /Cr-/ words vs. control /Cvr-/ words
  – C = {b,d,g}
  – following V = {i,a,o}

• Additional factors not discussed today:
  – real + nonce words
  – careful vs casual speech – results here are only from careful speech
Method

- Participants: 6 Turkish speakers from UCSC
- Terason ultrasound, ~50fps
- 5 repetitions in a carrier sentence
Method

- Output takes the form \([C(v_1)rV_2\ldots]\)
  - I analyze the interval between /C/ and /r/: \(v_1\)
    (which may or may not sound like a vowel)
- Praat: Annotate audio to get time stamps for \(v_1\)
- Edgetrak: Trace tongue contour in each frame from \(v_1\)
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Thank you, Mallika!

Thank you, Serene!
Preview of results

- Insertion is gradient
- Insertion is variable
- (Apparent) harmony is variable
- Inserted vowels appear targetless
Gradience

- Categorical process: bimodal distribution of $v_1$ durations
- Gradient process: unimodal distribution of $v_1$ durations
Duration of v1 interval in Cr vs Cvr words (all subjects)

- Underlying vowel (Cvr)
- Underlying cluster (Cr)
Variability

- How much of the time does insertion apply?
- How much of the time does harmony apply?

These are really questions about perception.
Variability

- How much of the time does insertion apply?
  Are /Cr/ tokens *perceived* as
  [Cr] (without insertion), or
  [Cv₁r] (with insertion)?

- How much of the time does harmony apply?
Variability

- How much of the time does insertion apply?
- How much of the time does harmony apply?

When a vowel is perceived, what is its *perceived* quality?
Variability

• How much of the time does insertion apply?
• How much of the time does harmony apply?

Perception experiment
  – with 9 phonetically trained coders
Predictions for perceptual results based on previous descriptions

Vowel insertion (all speakers)

If insertion occurs about half the time, and harmony always applies, results would look like this. Cf. Clements & Sezer, 1982; Yıldız 2010
Actual perceptual results

Vowel insertion (all speakers)
Insertion is perceived about half the time, and harmony is perceived much less than half the time.
**Gestural analysis**

- **Goal**: Compare the gestures for perceived inserted $v_1$ in /Cr/ vs. /Cv_1r/ words

- **Hypothesis**: Though these are perceptually the same, they are grammatically (and therefore gesturally) different

- **Corollary**: Though [Cr] and [Cvr] productions are perceptually different, all /Cr/ words are grammatically (and gesturally) the same
Gestural analysis

**Gestures for targeted $v_1$:**
- Both $v_1$ target and surrounding targets shape tongue position

**Gestures for targetless $v_1$:**
- No $v_1$ target, so only the surrounding targets shape tongue position

**C, r and $V_2$ targets will influence an intrusive, targetless $v_1$ more than an underlying, targeted $v_1**
Gestural analysis

• SSANOVAs: shows average tongue positions
  – for underlying v₁ vs. perceived inserted v₁
  – across multiple repetitions
  – within one speaker
  – within a C*V₂ condition
    
    For each condition, I will show SSANOVAs for all speakers who “inserted” enough

• Confidence intervals around each line show significant differences between tongue position in different words
/Cr/ tokens track together, whether a vowel was perceived (green) or not (yellow).
Perceived v in /Cr/ words is fronter: shows more influence of V₂

/Cl/ tokens track together, whether a vowel was perceived (green) or not (yellow)

Speaker 7
Perceived v in /Cr/ words is fronter: shows more influence of $V_2$. 
Perceived v in /Cr/ words shows influence of /r/.

/Cr/ tokens track together, whether a vowel was perceived (green) or not (yellow).
/Cr/ tokens track together, whether a vowel was perceived or not
Perceived v in /Cr/ words is fronter, shows more influence of $V_2 = /i/$.

/Cr/ tokens track together, whether a vowel was perceived or not.
No real gestural difference between /Cr/ and /Cvr/!

Perceived vowel in /Cr/ words is higher/backer – shows more influence from /g/?
No significant differences. But we don’t have tokens perceived without insertion, to compare to the tokens perceived with insertion.
Perceived v in /Cr/ words is lower, shows more influence of $V_2 = /a/$
No real gestural difference between /Cr/ and /Cvr/!
The graph shows the midpoints of various backness values for different speakers. The x-axis represents backness (px), while the y-axis represents height (px). The following curves are displayed:

- Yellow dotted line: bro (2)
- Green dashed line: b[u]ro (3)
- Blue solid line: buro (5)

The graph is labeled with 'buro midpoint' and 'Speaker 4', indicating the data is specific to Speaker 4.
/Cr/ tokens track together, whether a vowel was perceived (green) or not (yellow)
/Cr/ tokens track together, whether a vowel was perceived (green) or not (yellow). /Cr/ words are higher – greater influence of /b/.
Gestural results

- Underlying form (/Cr/ vs /Cvr/) predicts gestural similarity better than perceived form ([Cr] vs [Cvr])
  - Sometimes there is no gestural difference between [Cr] words and underlying vowels
- Perceived inserted vowels in /Cr/ words are more influenced by surrounding context than underlying vowels are
  - Whether C, r, or V₂ has the greatest influence depends on the condition and speaker
Gestural results

- These results support the hypothesis that the perceived inserted $v_1$ in /Cr/ is gesturally, and therefore grammatically, different from the underlying vowel in /Cv_1r/ words.
Conclusion

• Onset-repair in Turkish is
  – not a grammatical (phonological) process,
  – but a gestural / perceptual (phonetic) process
    • Gradient, variable; perceived inserted vowel differs gesturally from underlying vowels
Conclusion

- Onset-repair in Turkish
  - illustrates the non-linear mapping between grammar and perception

<table>
<thead>
<tr>
<th></th>
<th>Same in grammar</th>
<th>Same in gestures</th>
<th>Same in perception</th>
</tr>
</thead>
<tbody>
<tr>
<td>/Cr/ → [Cvr]</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>/Cr/ → [Cr]</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>/Cr/ → [Cvr]</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
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<td>sometimes</td>
</tr>
<tr>
<td>/Cr/ → [Cr]</td>
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<td></td>
<td>✓</td>
</tr>
<tr>
<td>/Cvr/</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Conclusion

- Onset-repair in Turkish
  - illustrates the non-linear mapping between grammar and perception
  - demonstrates the need for production and perception studies in phonology
Thank you!

• Acknowledgements:
  – Mallika Pajjuri for Textgridding
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  – Jaye Padgett
  – Grant McGuire
Selected references


Variability

• About ~45% of tokens coded with insertion
  (157 / 352 Cr tokens)
  – Insertion is either phonetic, or phonological but optional

• Most inserted vowels were coded as [ı]
  (108/157 = 68.8%)
  – Harmony is either phonetic, or phonological but optional
Durational differences

- Underlying vowels are quite short
- Inserted vowels are significantly shorter ($p<0.001$)
  - but not for S2 or S4 ($p>0.1$)
- Some no-insertion tokens are as long as some underlying vowels