Dynamics of Speech Perception

Dinafon

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Issues

1. Speech sounds are often perceived as differing from their contexts (Repp, 1982),
2. Competing explanations:
   a. Gesturalist: Listeners parse the acoustic effects of coarticulation into their articulatory sources = compensate for coarticulation (Fowler & Smith, 1986; Fowler, 2006),
   b. Auditorist: Acoustic properties of adjacent speech sounds contrast auditorily with one another (Diehl & Walsh, 1989; Lotto & Kluender, 1998; Lotto & Holt, 2006);
3. But what if:
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Theory-neutral descriptions

1. If a target sound is perceived as differing from its context, as both the gesturalist and auditorist accounts predict, the target "dissimilates" perceptually from its context,
2. If a target sound is perceived as resembling its context, which the gesturalist account prohibits, the target "assimilates" perceptually to its context.

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Experiment 1:
Categorizing consonants in VC sequences

1. Target: C = [t–p] continuum,
2. Context: V = preceding [i] vs [u],
3. More "p" after [i] than [u] = compensation / contrast:
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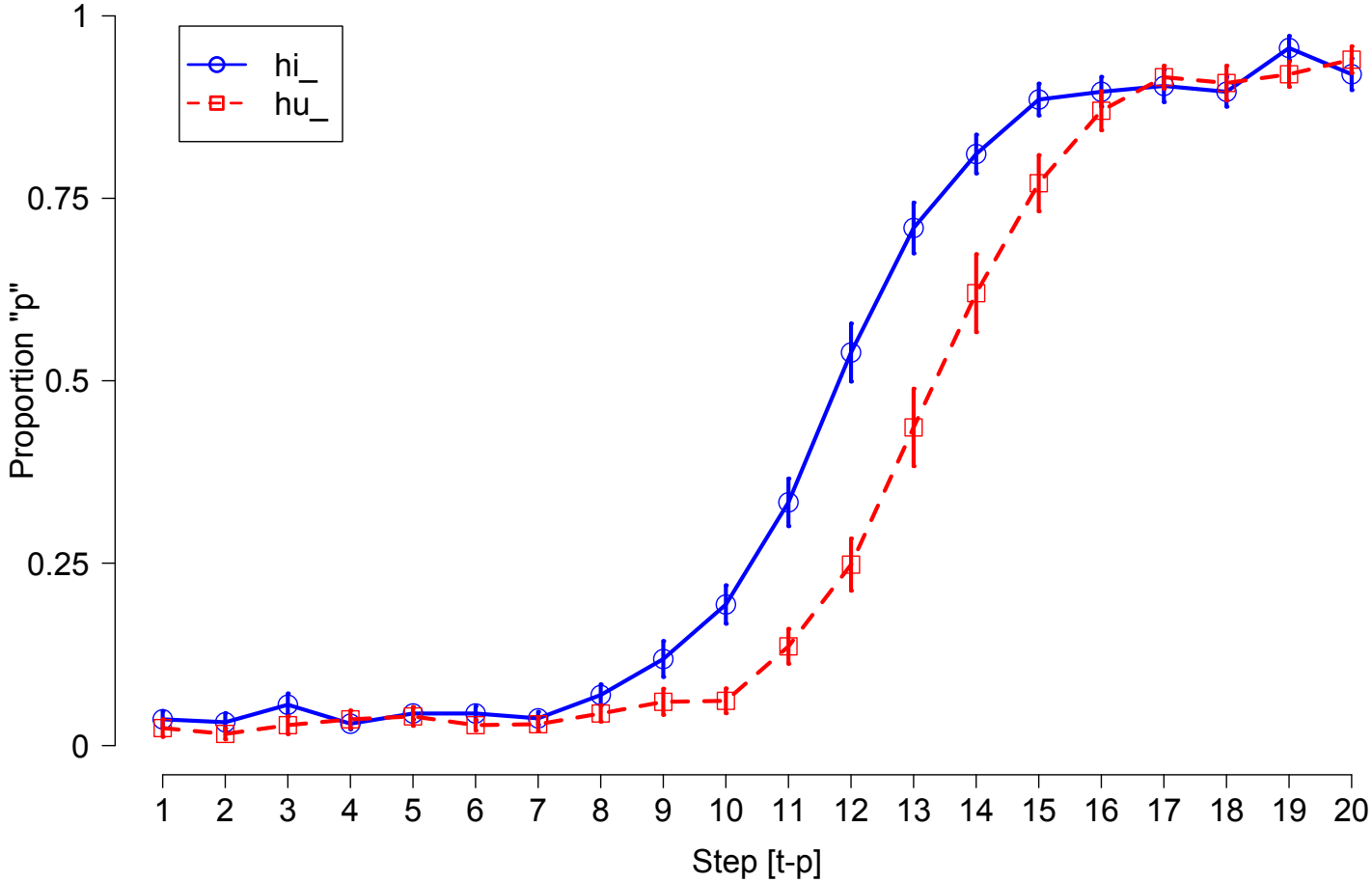

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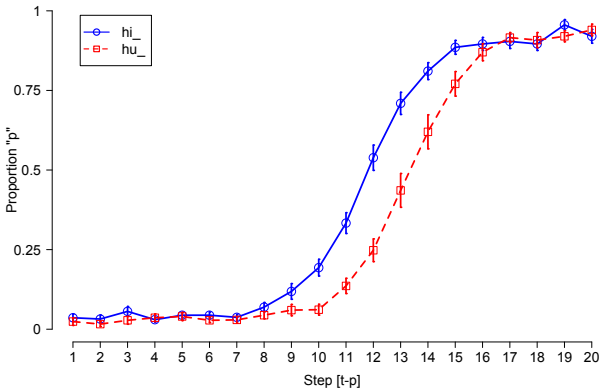

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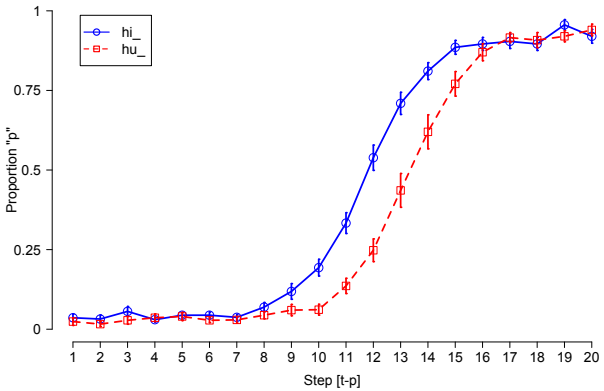

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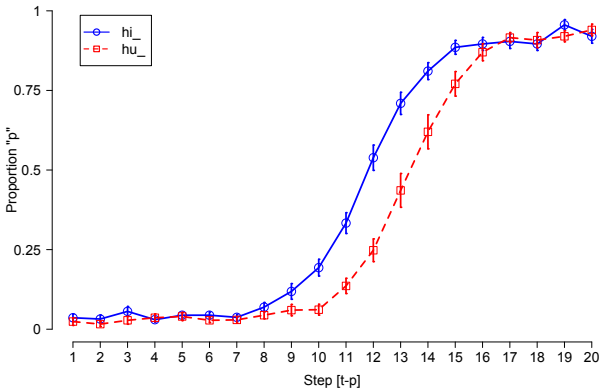

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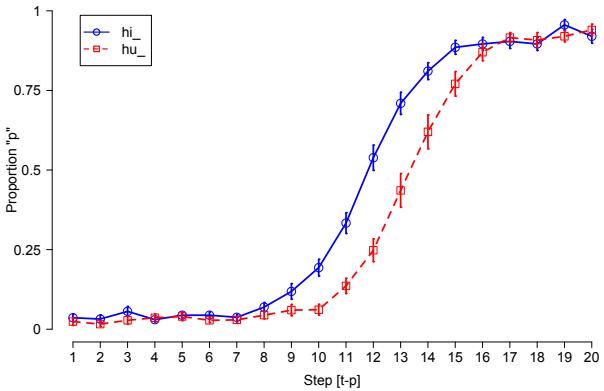

Effect	Estimate	*se*	*z*	*p*
(Intercept)	-3.7906	0.5148	-7.363	1.8e-13
Step	0.8526	0.1003	8.501	< 2e-16
Context	1.2219	0.2751	4.442	8.9e-06

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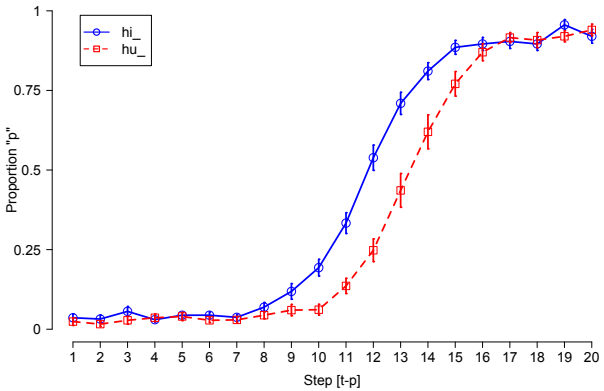

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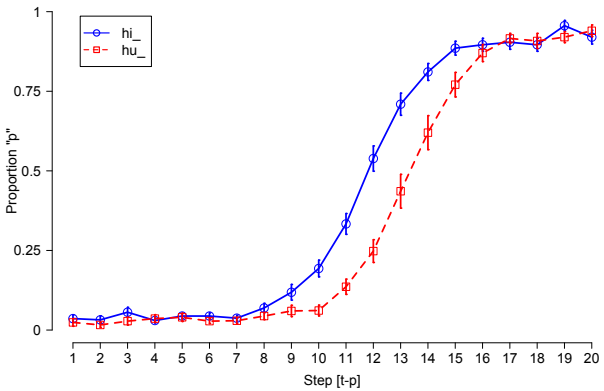

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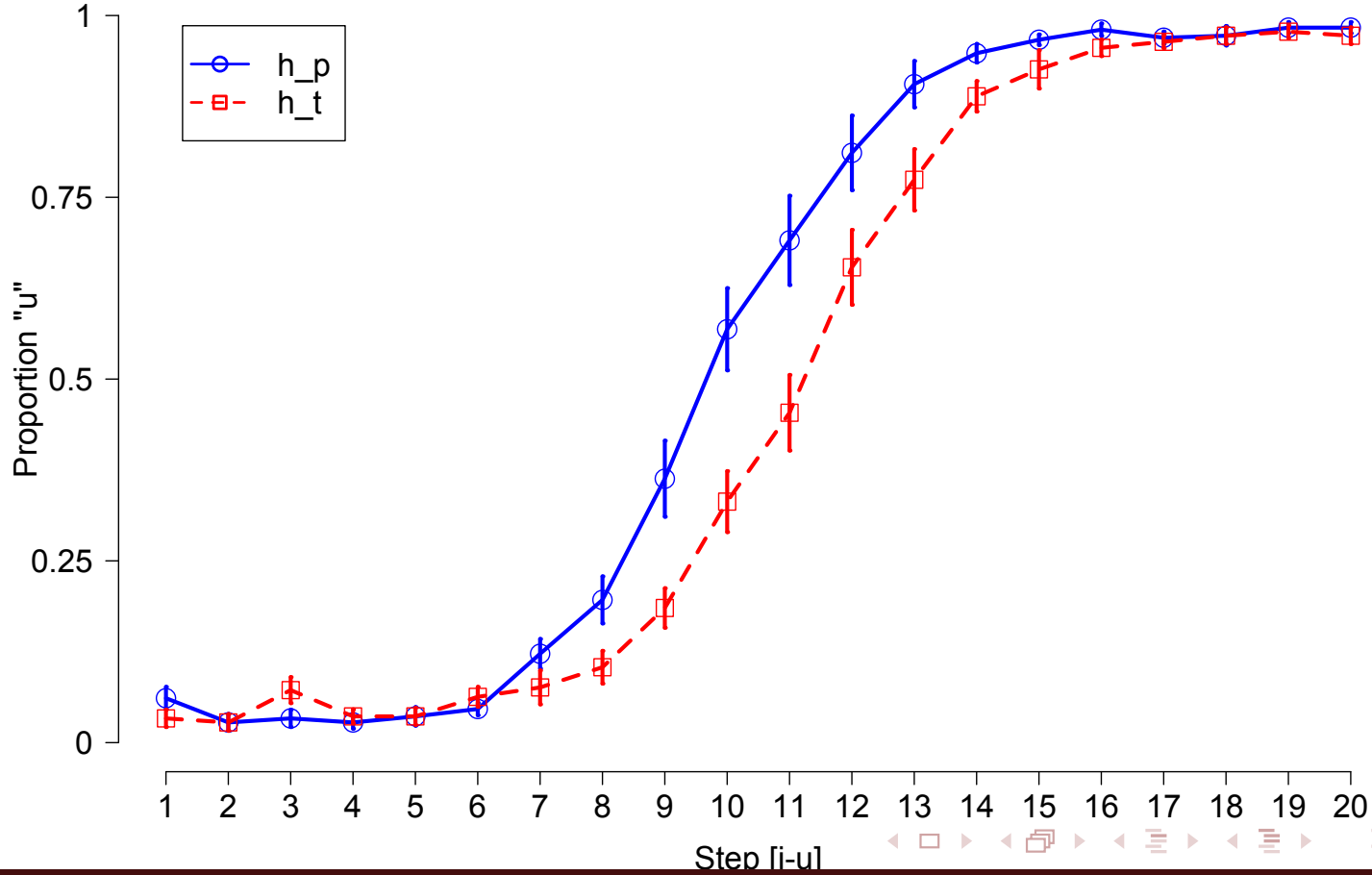

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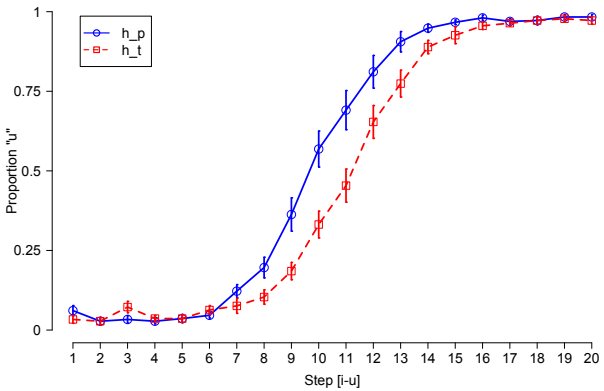

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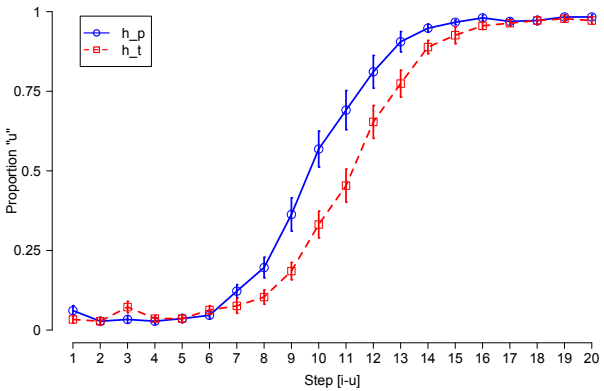

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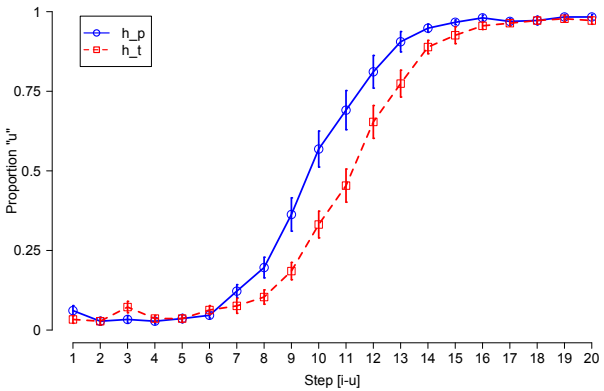

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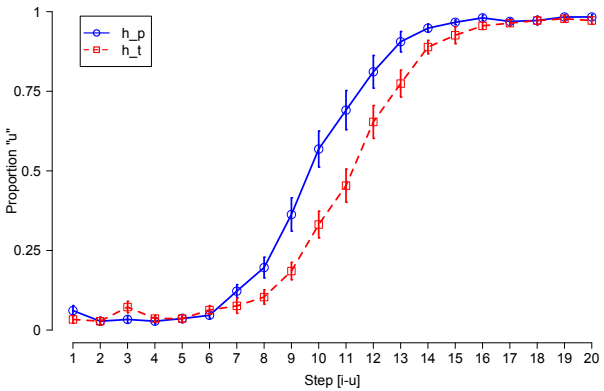

Effect	Estimate	*se*	*z*	*p*
(Intercept)	-0.02596	0.45007	-0.058	0.954
Step	0.86423	0.11068	7.808	5.80e-15
Context	1.35828	0.29326	4.632	3.63e-06

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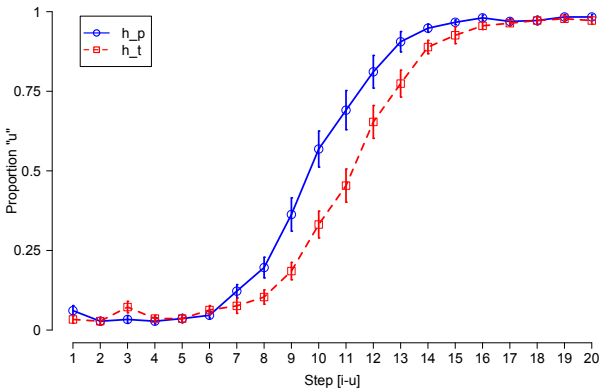

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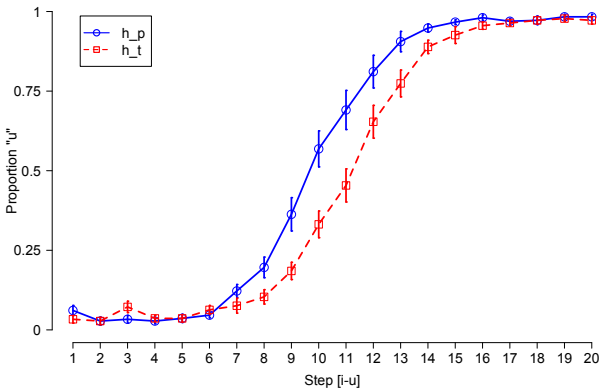

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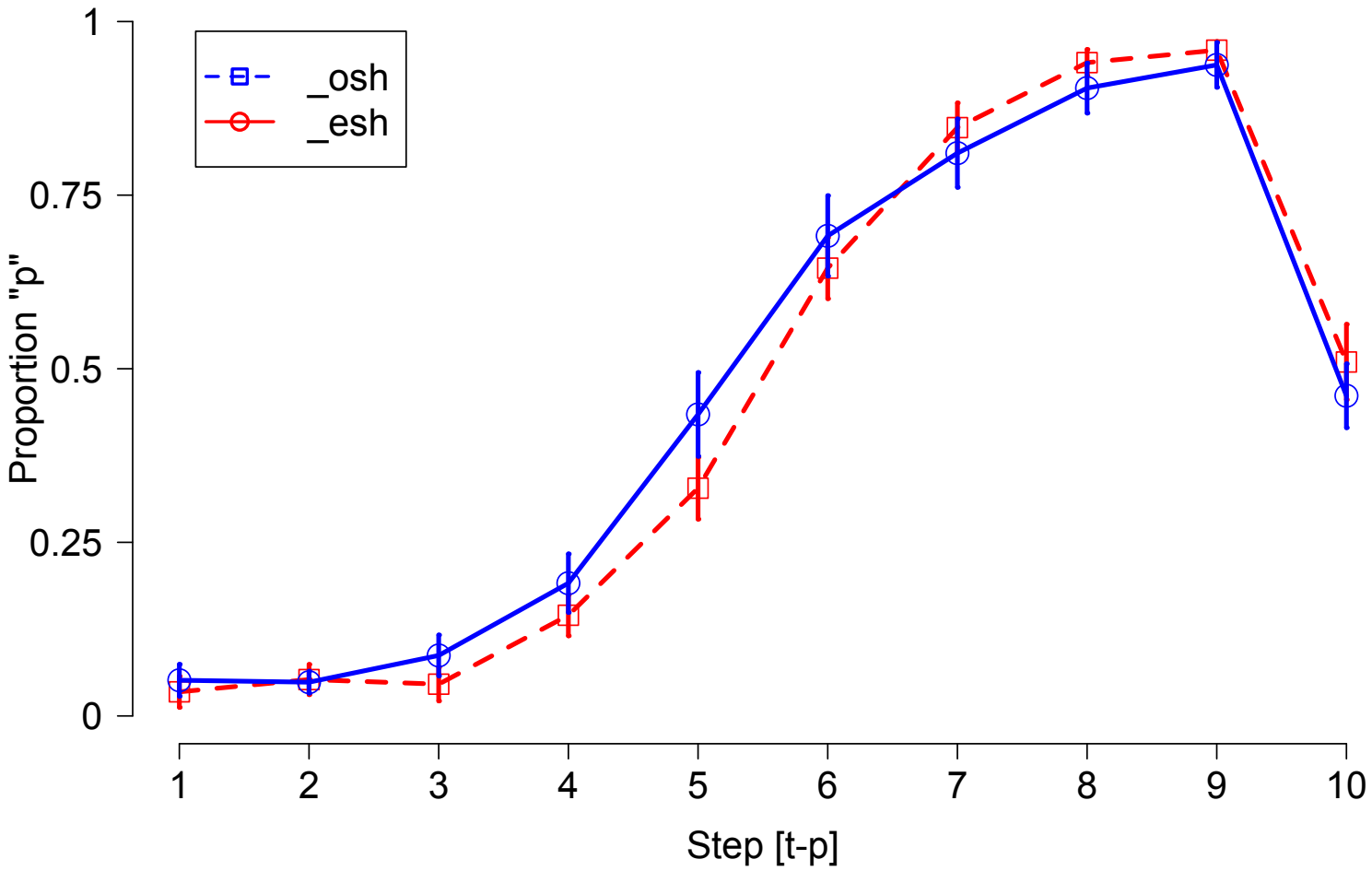

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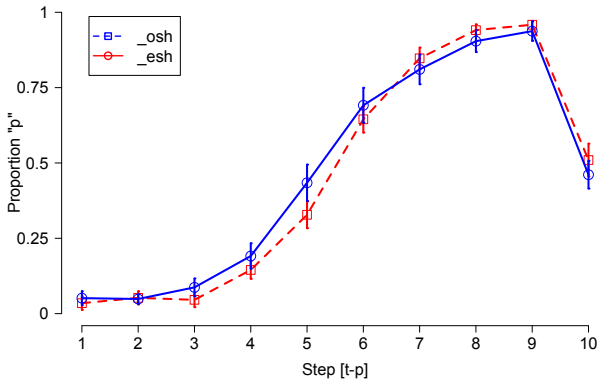

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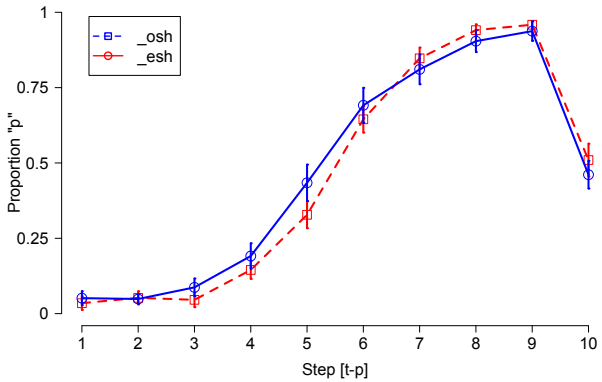

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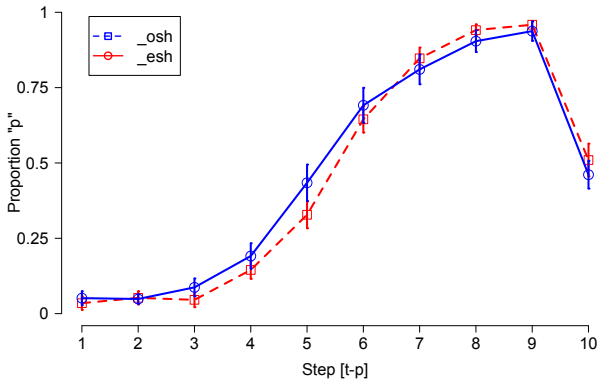

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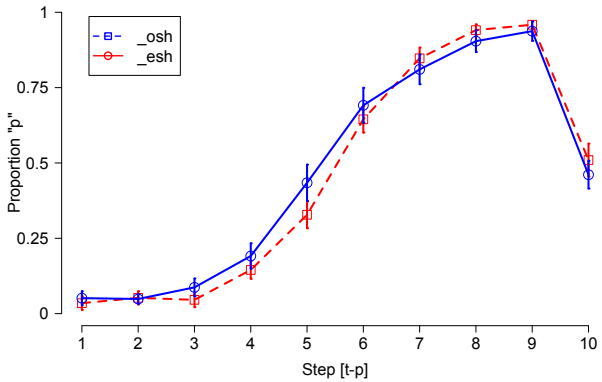

Effect	Estimate	*se*	*z*	*p*
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Step	0.3223	0.0295	10.924	< 2e-16
Context	0.0214	0.1291	0.166	0.8684

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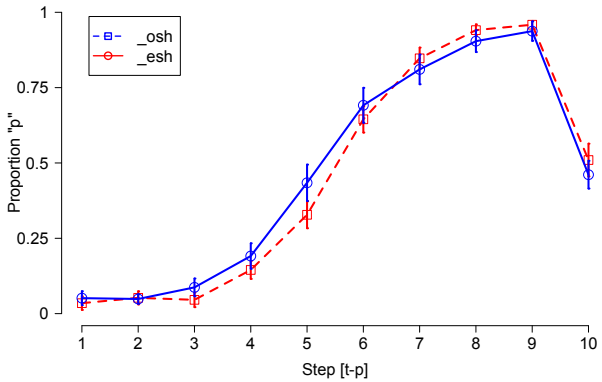
1. Target: C = [t–p] continuum,
2. Context: V = following [e] vs [o]:
4. Model: "p:t" ~ Step + Context + (1 + Step + Context | Subject)
   a. Step: Increasing [t–p], + = more "p" as step increases
   b. Context: _o = 1, _e = -1;



Effect	Estimate	*se*	*z*	*p*
(Intercept)	-0.4098	0.1618	-2.533	0.0113
Step	0.3223	0.0295	10.924	< 2e-16
Context	0.0214	0.1291	0.166	0.8684

Experiment 3: Categorizing consonants in CV sequences

1. Target: C = [t–p] continuum,
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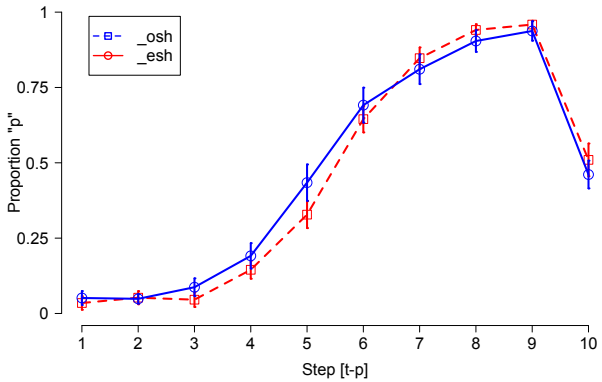
4. Model: "p:t" ~ Step + Context + (1 + Step + Context | Subject)
   a. Step: Increasing [t–p], + = more "p" as step increases
   b. Context: _o = 1, _e = -1; + = more "p" before [o] than [e]



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Experiment 4:
Categorizing vowels in CV sequences

1. Target: V = [e–o] continuum,
2. Context: C = preceding [t] vs [p]:
4. Model: "p:t" ~ Step + Context + (1 + Step + Context | Subject)
   a. Step: Increasing [e–o],
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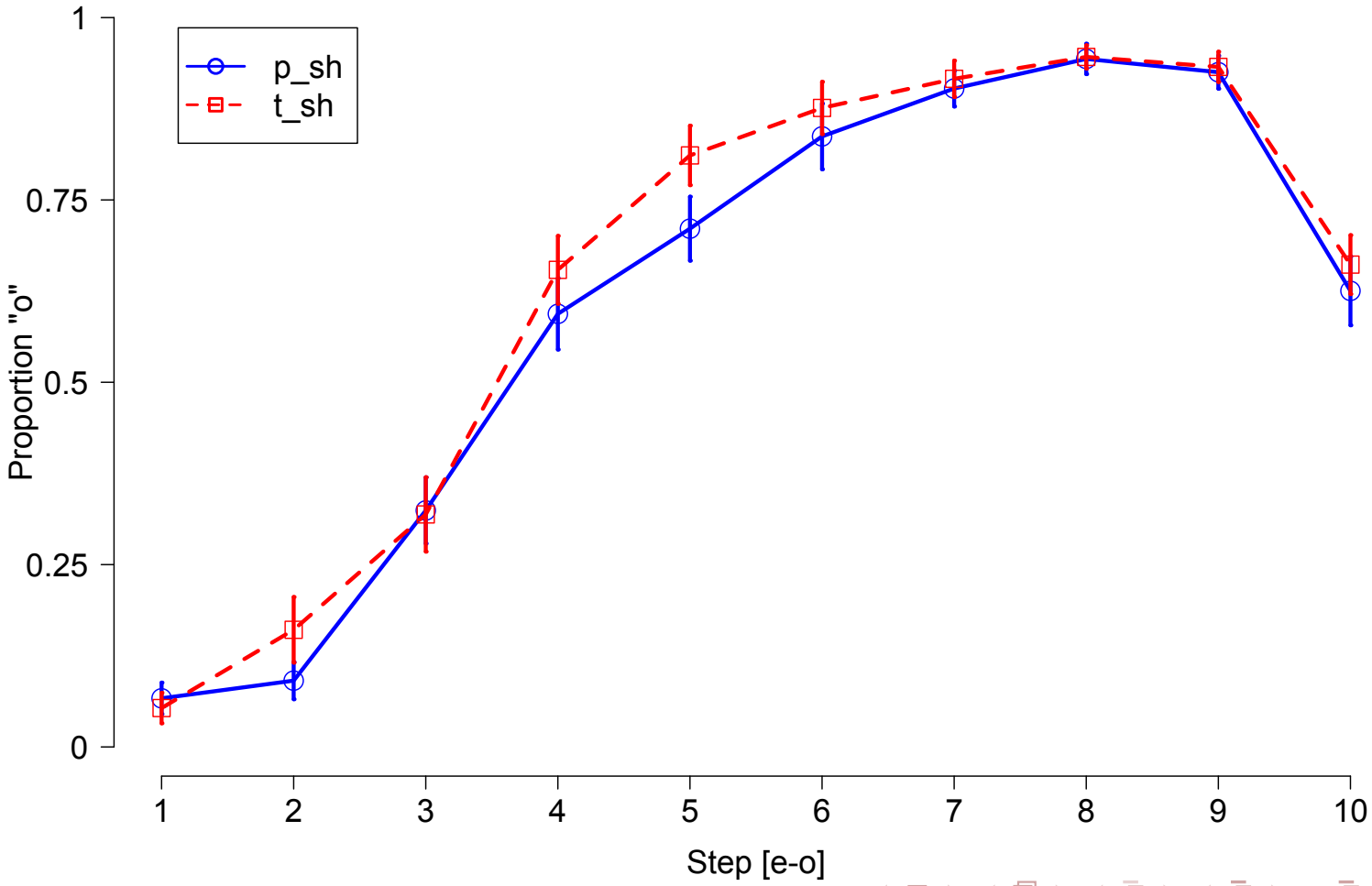

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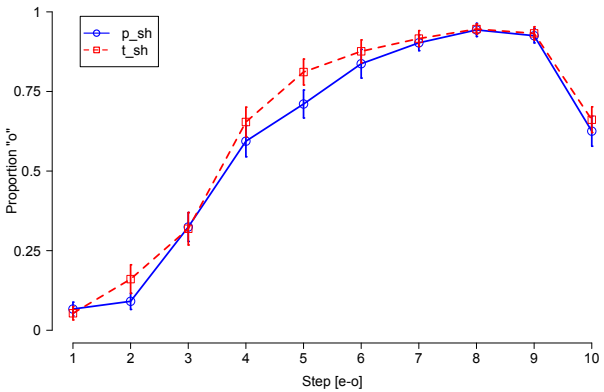

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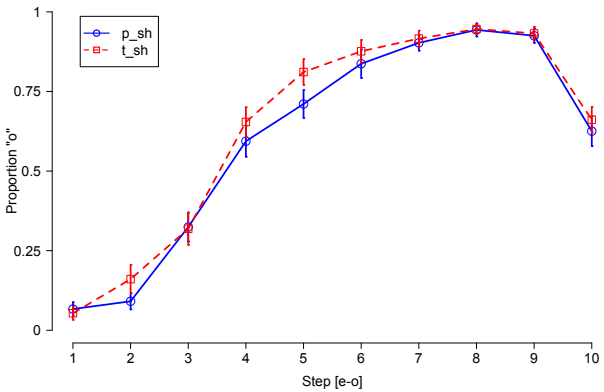

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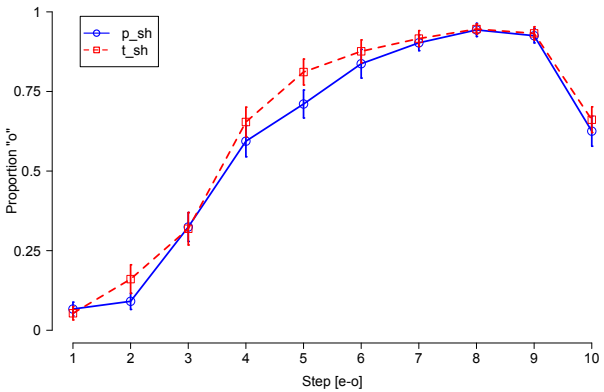

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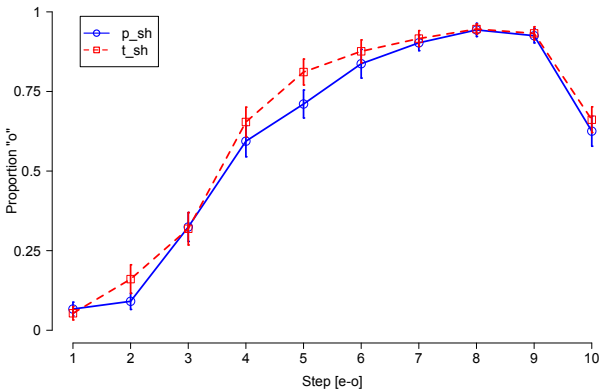

Effect	Estimate	*se*	*z*	*p*
(Intercept)	0.99208	0.20186	4.915	8.89e-07
Step	0.36100	0.03298	10.948	< 2e-16
Context	0.16165	0.12699	1.273	0.203

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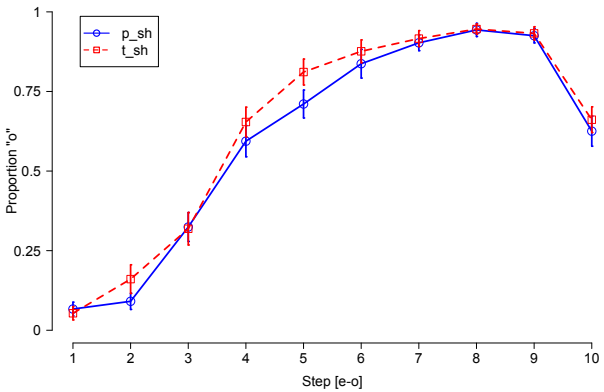

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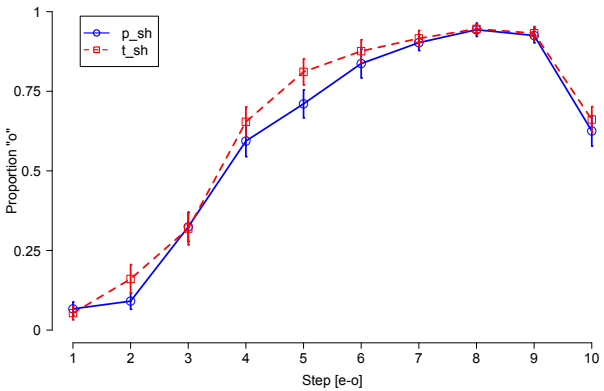

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Outline

Experiment 5: Categorizing vowels with matching vs mismatching transitions and bursts

1. Target: V = [i–u] continuum,
2. Contexts: Cs with transitions and bursts that:
3. Vp–p, Vt–t = Experiment 2:
4. Vp–t, Vt–p:

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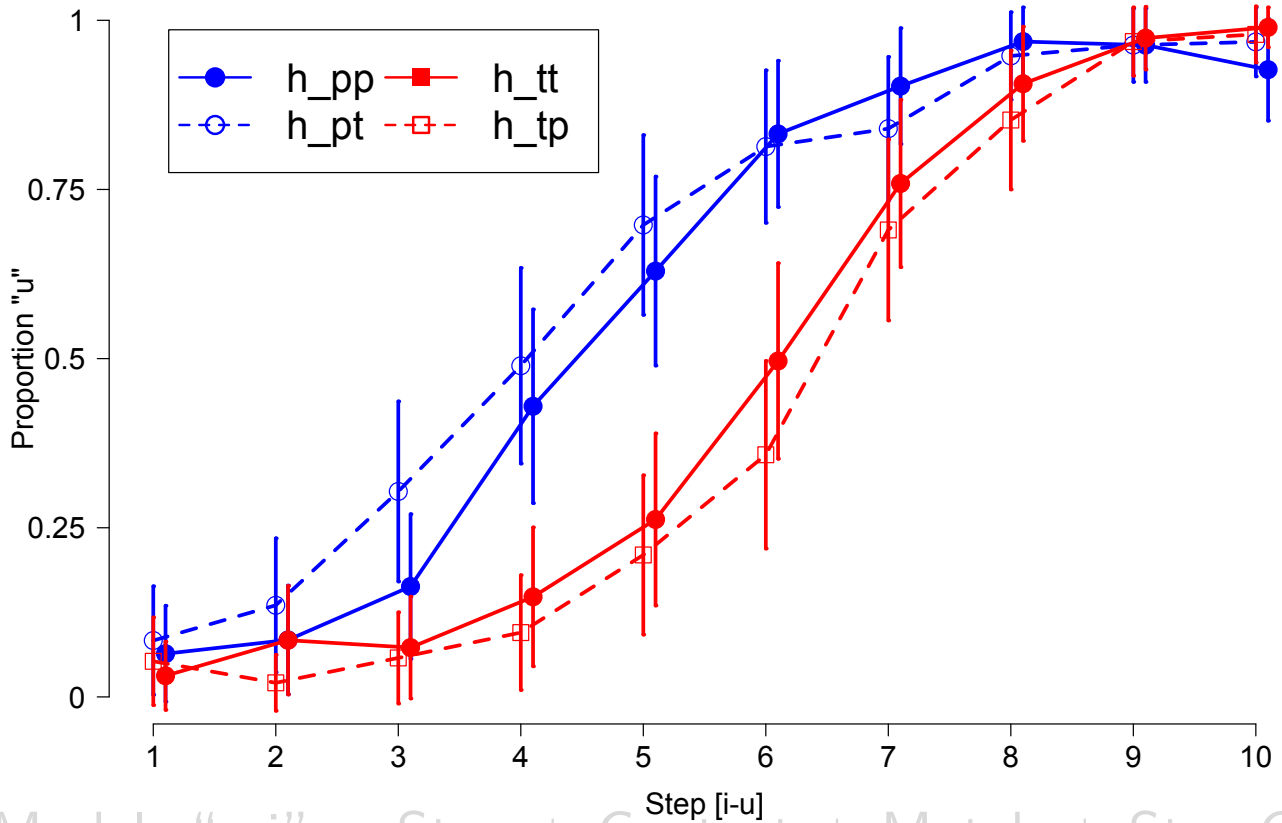
Experiment 5: Categorizing vowels with matching vs mismatching transitions and bursts (n=12)



Model: "u:i" ~ Step + Context + Match + Step:Context + Context:Match + (1 + ... | Subject)

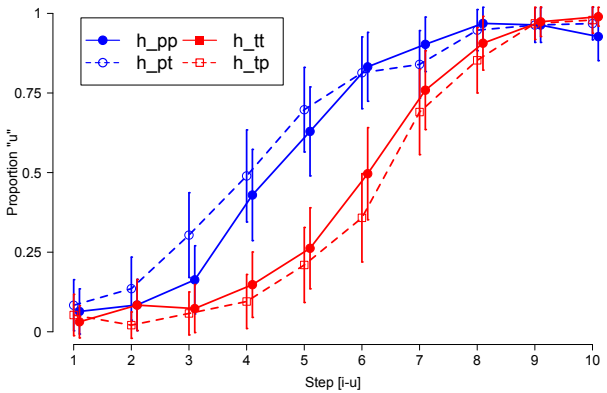
a Step:

b Context:

Experiment 5: Categorizing vowels with matching vs mismatching transitions and bursts (n=12)

Model: "u:i" ~ Step + Context + Match + Step:Context + Context:Match + (1 + ... | Subject)

a Step:
b Context:
c Match:
d Step:Context:
e Context:Match:



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Model: "u:i" ~ Step + Context + Match + Step:Context + Context:Match + (1 + ... | Subject)

a Step:
b Context:
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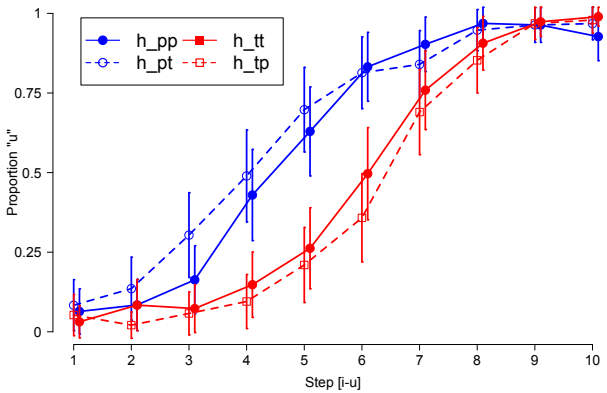

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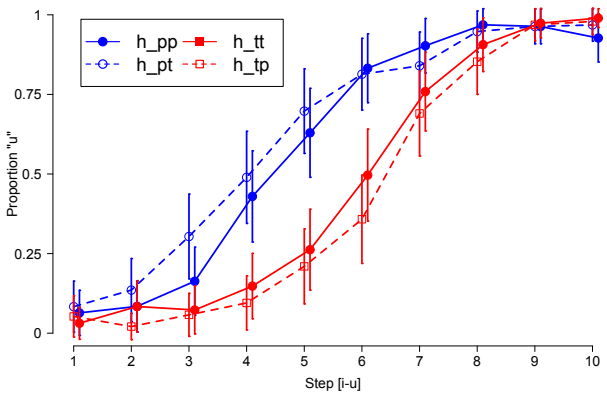
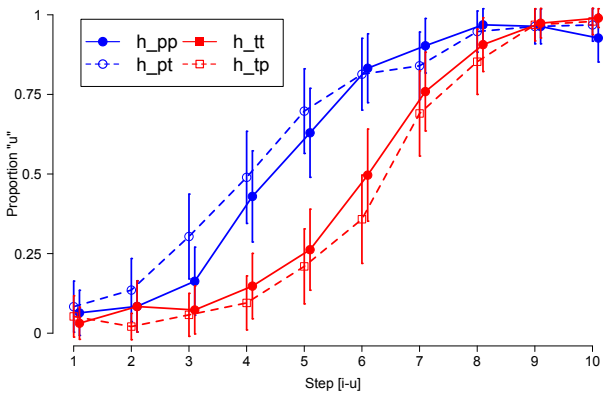


Effect	Estimate	*se*	*z*	*p*
(Intercept)	0.36746	0.48384	0.759	0.447570
Step	0.61996	0.05645	10.982	< 2e-16
Context	1.06727	0.12328	8.657	< 2e-16
Match	0.07719	0.04976	1.551	0.120845
Step x Context	-0.08400	0.02459	-3.415	0.000637
Context x Match	-0.21915	0.06262	-3.499	0.000466

Experiment 5: Categorizing vowels with matching vs mismatching transitions and bursts (n=12)

Model: "u:i" ~ Step + Context + Match + Step:Context + Context:Match + (1 + ... | Subject)

a Step: + = more "u" as step increases
b Context:
c Match:
d Step:Context:
e Context:Match:



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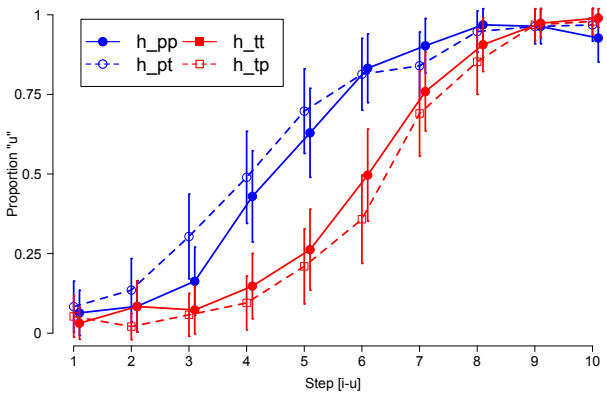

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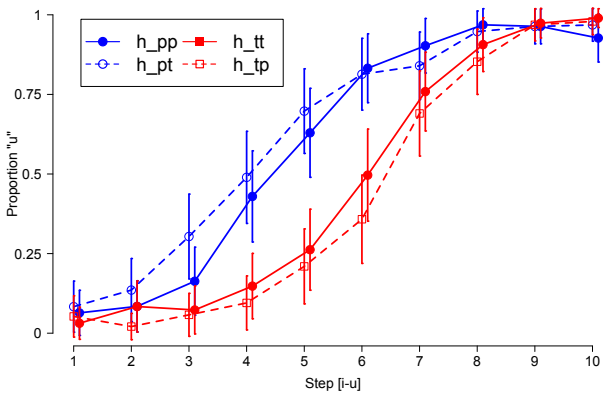

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a. Step: + = more "u" as step increases
b. Context: + = more "u" before [p] than [t]
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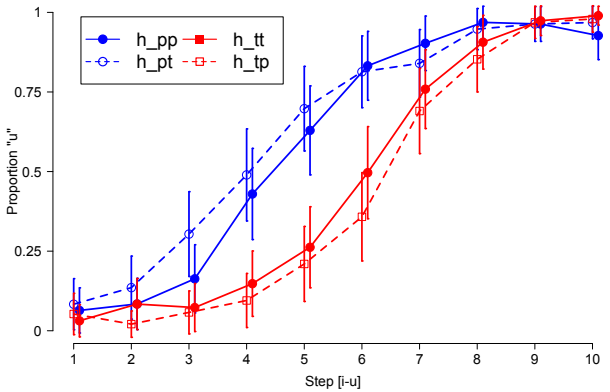
e. Context:Match:



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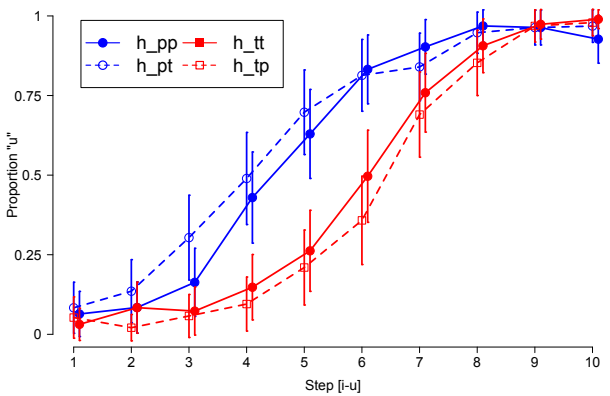

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Outline

Background summary

1. Assimilation occurs when context follows target:
   a. Exp 2: V ⟶ "u" / _ [p], and "i" / _ [t]
   b. Exp 3: C ⟶ "p" / _ [o], and "t" / _ [e];
2. Dissimilation occurs when context precedes target:
   a. Exp 1: C ⟶ "p" / [i] _, and "t" / [u] _,
   b. Exp 4: V ⟶ "o" / [t] _, and "e" / [p] _;
3. Exp 5: Assimilation occurs even when categorial identity of context differs,
4. Assimilation versus dissimilation depends on order of segments, not manner,
5. Assimilation affects both Vs and Cs as targets and contexts in #CV and VC# sequences.

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Outline

Preliminary interpretation: Order

1. The acoustic characteristics of transitions between consonants and vowels are determined by both articulations,
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Outline

Misparsing: Hypothesis and its predictions

1. Misparse hypothesis: Assimilation results from attributing formant transitions of the following context to the preceding target,
2. Predictions: Expect more assimilation with:
   a. Longer formant transitions (relative to steady state),
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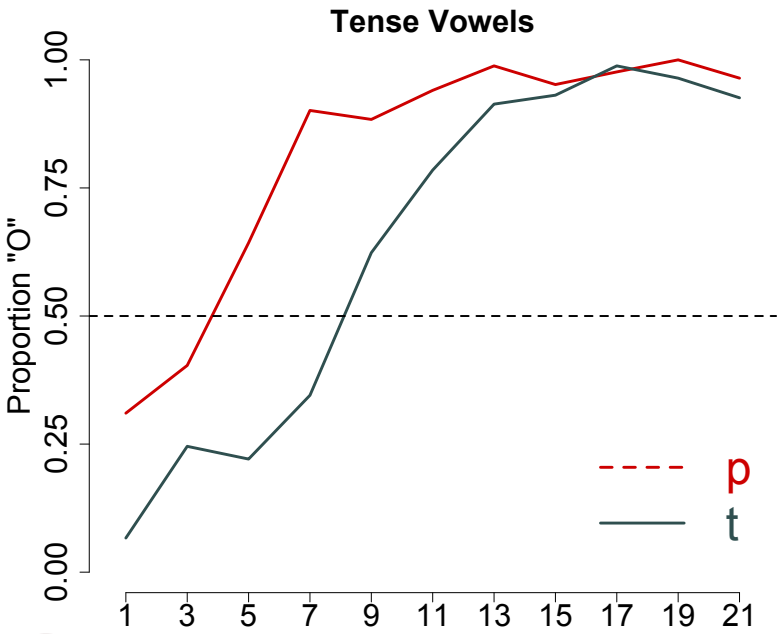

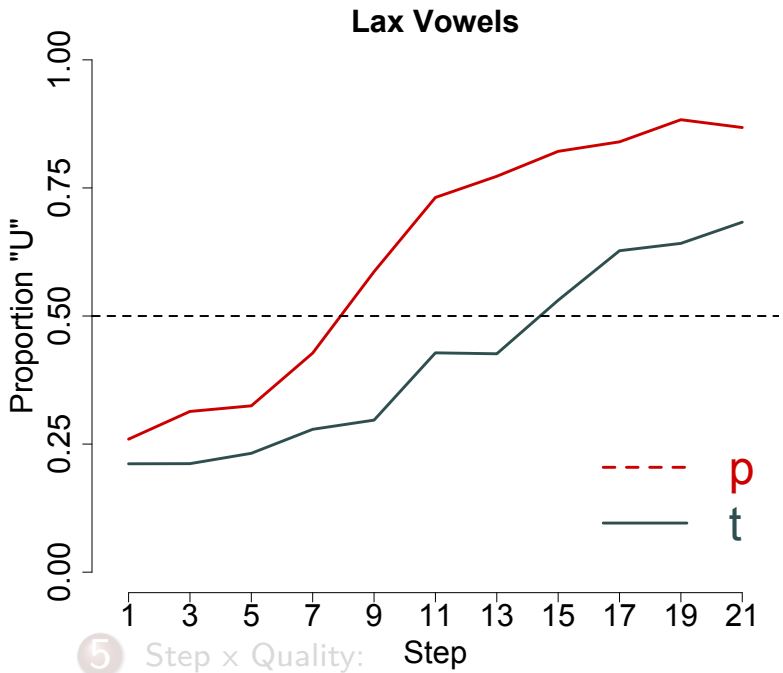

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(Intercept)	0.946157	0.324457	2.916	0.00354
Step	0.315106	0.043125	7.307	2.74e-13
Quality	-0.769524	0.137745	-5.587	2.32e-08
Context	0.693841	0.287554	2.413	0.01583
Step x Quality	-0.078528	0.013753	-5.710	1.13e-08
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1. Participants misparse consonant's contributions to the transition's acoustics more across continuum with [lax] than [tense] vowels,
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1. Misparse hypothesis predicts that [lax] vowels are more often assimilated because their transitions are longer relative to their steady states,
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4. Durations = mean duration of longer tense and shorter lax vowels,
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    a. _ [p]: 30:70 > 50:50 > 70:30,
    b. _ [t]: 30:70 < 50:50 < 70:30.

Misparse 2: Predictions

1. Step: More "back" for more [back],
2. Quality: No main effect,
3. Context: More "back" before [p],
4. Ratio: No main effect,
5. Step x Quality: No interaction,
6. Step x Context: More "back" for more steps before [p],
7. Step x Ratio: Weaker effect of step for long transitions,
8. Quality x Context: More "back" when lax before [p],
9. Quality x Ratio: No interaction,
10. Context x Ratio. "back"
    a. _ [p]: 30:70 > 50:50 > 70:30,
    b. _ [t]: 30:70 < 50:50 < 70:30.

Misparse 2: Predictions

1. Step: More "back" for more [back],
2. Quality: No main effect,
3. Context: More "back" before [p],
4. Ratio: No main effect,
5. Step x Quality: No interaction,
6. Step x Context: More "back" for more steps before [p],
7. Step x Ratio: Weaker effect of step for long transitions,
8. Quality x Context: More "back" when lax before [p],
9. Quality x Ratio: No interaction,
10. Context x Ratio. "back"
    a. _ [p]: 30:70 > 50:50 > 70:30,
    b. _ [t]: 30:70 < 50:50 < 70:30.

Misparse 2: Predictions

1. Step: More "back" for more [back],
2. Quality: No main effect,
3. Context: More "back" before [p],
4. Ratio: No main effect,
5. Step x Quality: No interaction,
6. Step x Context: More "back" for more steps before [p],
7. Step x Ratio: Weaker effect of step for long transitions,
8. Quality x Context: More "back" when lax before [p],
9. Quality x Ratio: No interaction,
10. Context x Ratio. "back"
    a. _ [p]: 30:70 > 50:50 > 70:30,
    b. _ [t]: 30:70 < 50:50 < 70:30.

Misparse 2: Predictions

1. Step: More "back" for more [back],
2. Quality: No main effect,
3. Context: More "back" before [p],
4. Ratio: No main effect,
5. Step x Quality: No interaction,
6. Step x Context: More "back" for more steps before [p],
7. Step x Ratio: Weaker effect of step for long transitions,
8. Quality x Context: More "back" when lax before [p],
9. Quality x Ratio: No interaction,
10. Context x Ratio. "back"
    a. _ [p]: 30:70 > 50:50 > 70:30,
    b. _ [t]: 30:70 < 50:50 < 70:30.

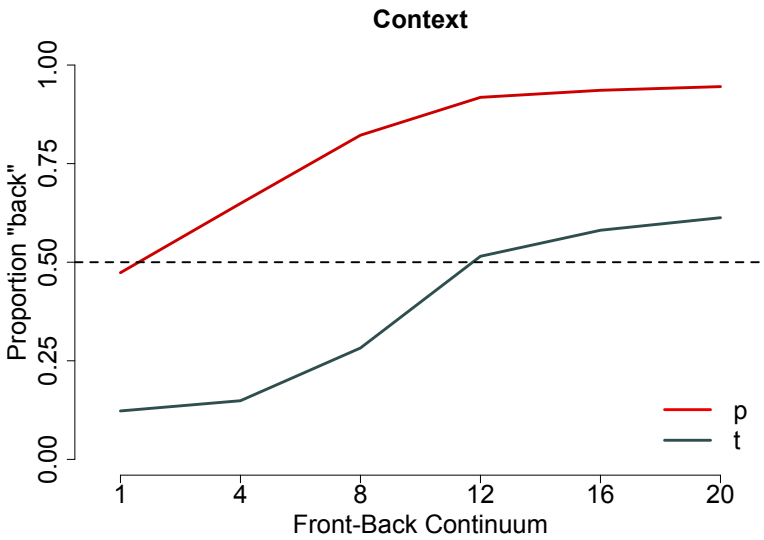
Misparse 2: Predictions

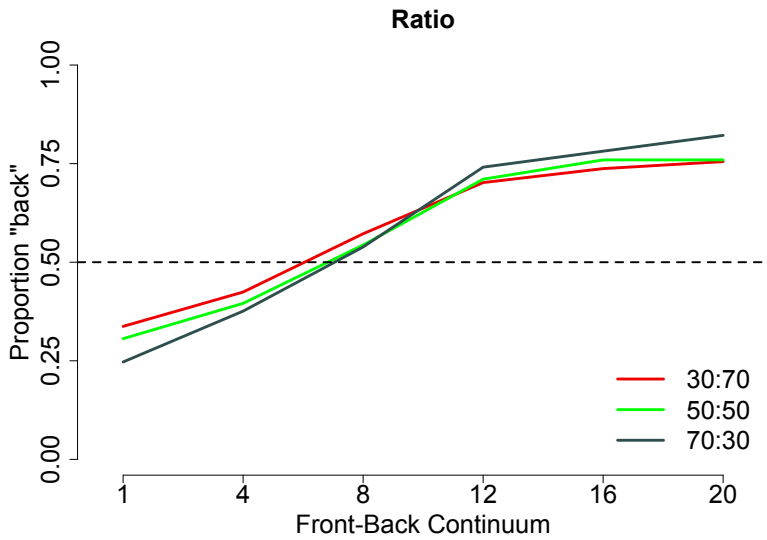
1. Step: More "back" for more [back],
2. Quality: No main effect,
3. Context: More "back" before [p],
4. Ratio: No main effect,
5. Step x Quality: No interaction,
6. Step x Context: More "back" for more steps before [p],
7. Step x Ratio: Weaker effect of step for long transitions,
8. Quality x Context: More "back" when lax before [p],
9. Quality x Ratio: No interaction,
10. Context x Ratio. "back"
    a. _ [p]: 30:70 > 50:50 > 70:30,
    b. _ [t]: 30:70 < 50:50 < 70:30.

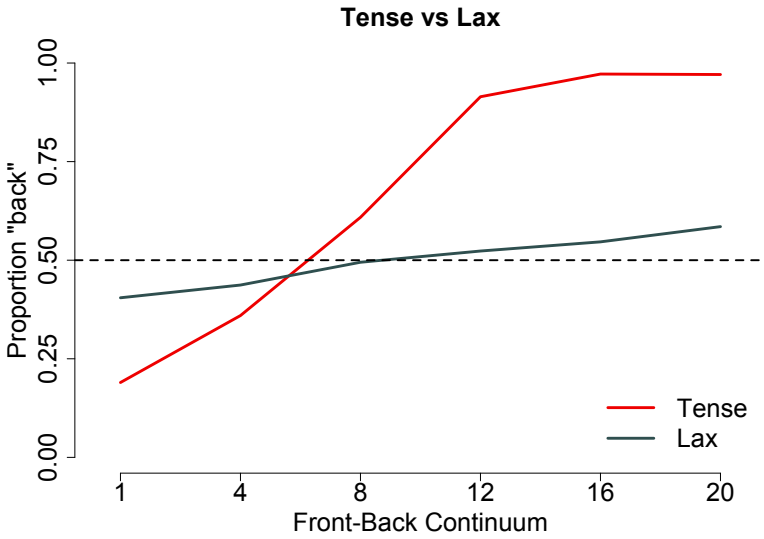
Misparse 2: Predictions

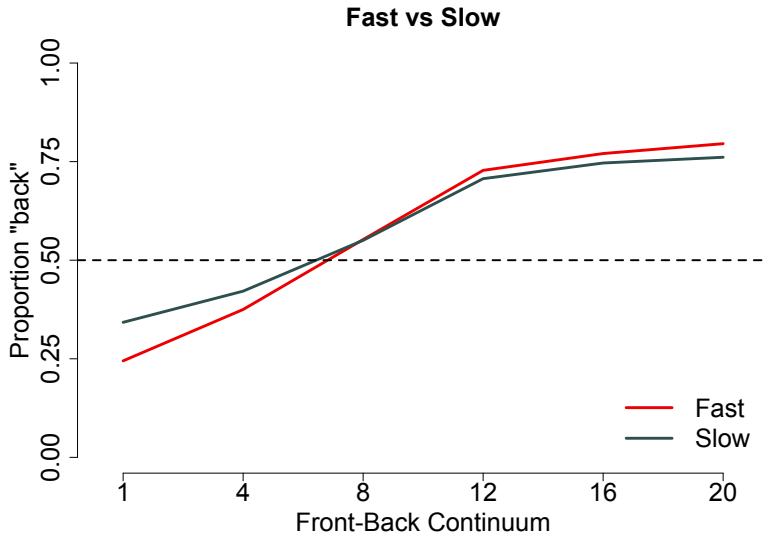
1. Step: More "back" for more [back],
2. Quality: No main effect,
3. Context: More "back" before [p],
4. Ratio: No main effect,
5. Step x Quality: No interaction,
6. Step x Context: More "back" for more steps before [p],
7. Step x Ratio: Weaker effect of step for long transitions,
8. Quality x Context: More "back" when lax before [p],
9. Quality x Ratio: No interaction,
10. Context x Ratio. "back"
    a. _ [p]: 30:70 > 50:50 > 70:30,
    b. _ [t]: 30:70 < 50:50 < 70:30.

Misparse 2: Main effects by Step

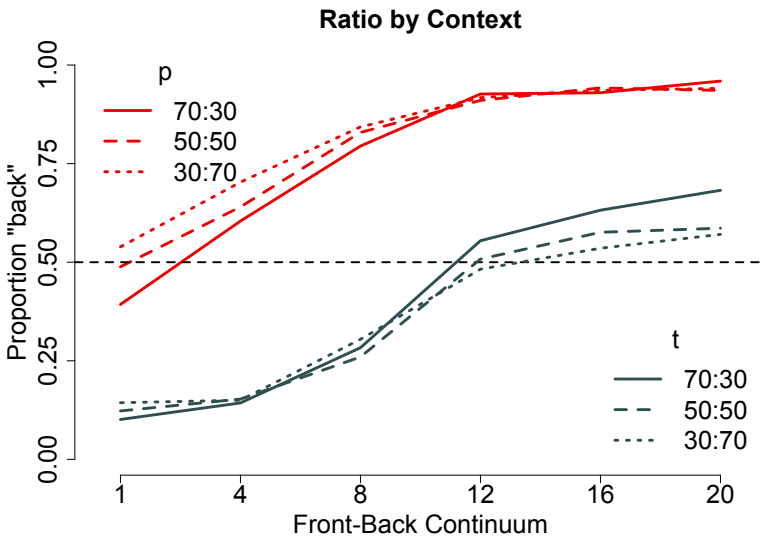


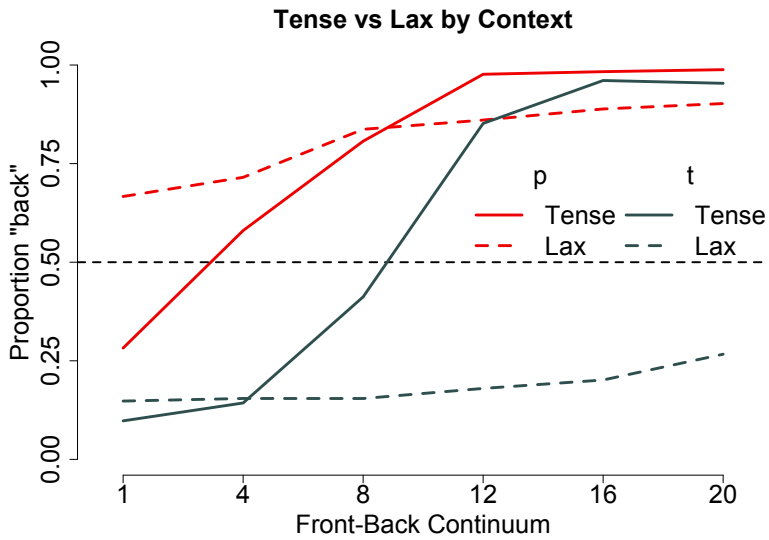


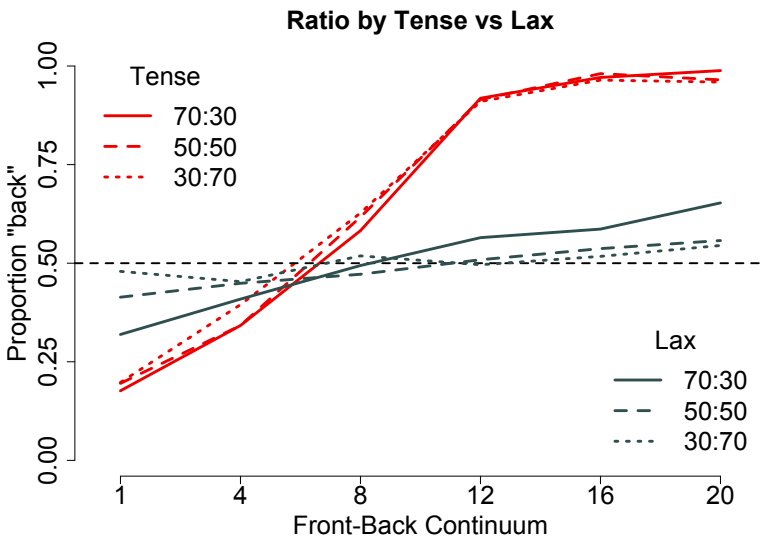


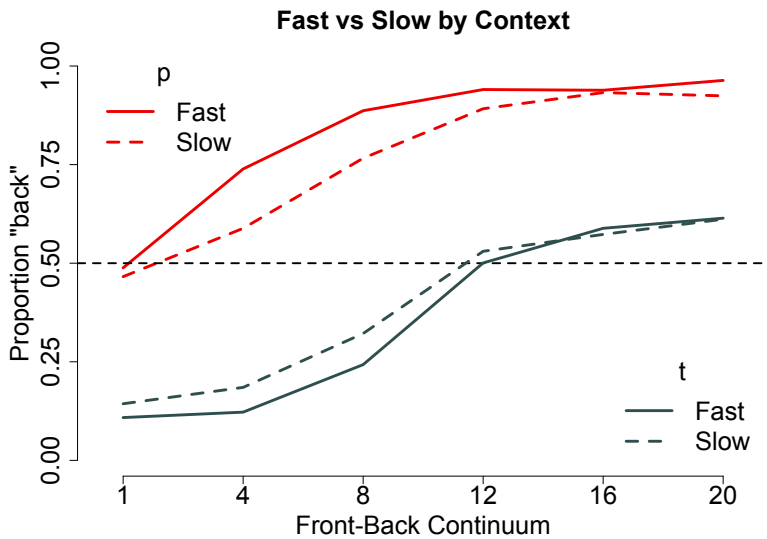


Misparse 2: Two-way interactions by Step









Misparse 2: Model

1. "back:front" ~ Step * Quality + Step * Ratio + Quality * Context * Ratio + (1 + Context + VowelQual + Step + Ratio | Subject)
2. Step: Increasing [e–o], [ɛ–ʌ],
3. Quality: lax = 1, tense = -1,
4. Context: _p = 1, _t = -1,
5. Ratio: 30:70 = 1, 50:50 = 0, 70:30 = -1;
6. Step x Quality:
7. Step x Ratio:
8. Quality x Context:
9. Context x Ratio:
10. Quality x Context x Ratio:

Effect	Estimate	*se*	*z*	*p*
(Intercept)	1.057584	0.204428	5.173	2.30e-07
Step	0.331160	0.022154	14.948	< 2e-16
Quality	-1.187681	0.173749	-6.836	8.17e-12
Context	1.689806	0.202223	8.356	< 2e-16
Ratio	-0.023682	0.044346	-0.534	0.5933
Step x Quality	-0.240075	0.007883	-30.454	< 2e-16
Step x Ratio	-0.042858	0.006914	-6.199	5.69e-10
Quality x Context	0.294180	0.031595	9.311	< 2e-16
Context x Ratio	0.099796	0.035302	2.827	0.0047
Quality x Context x Ratio	0.087189	0.033911	2.571	0.0101

Misparse 2: Model

1. "back:front" ~ Step * Quality + Step * Ratio + Quality * Context * Ratio + (1 + Context + VowelQual + Step + Ratio | Subject)
2. Step: Increasing [e–o], [ɛ–ʌ],
3. Quality: lax = 1, tense = -1,
4. Context: _p = 1, _t = -1,
5. Ratio: 30:70 = 1, 50:50 = 0, 70:30 = -1;
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8. Quality x Context:
9. Context x Ratio:
10. Quality x Context x Ratio:

Effect	Estimate	*se*	*z*	*p*
(Intercept)	1.057584	0.204428	5.173	2.30e-07
Step	0.331160	0.022154	14.948	< 2e-16
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Context	1.689806	0.202223	8.356	< 2e-16
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Misparse 2: Model

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9. Context x Ratio:
10. Quality x Context x Ratio:

Effect	Estimate	*se*	*z*	*p*
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2. Step: Increasing [e–o], [ɛ–ʌ], + = more "back" as step increases
3. Quality: lax = 1, tense = -1, – = fewer "back" when lax
4. Context: _p = 1, _t = -1,
5. Ratio: 30:70 = 1, 50:50 = 0, 70:30 = -1;
6. Step x Quality:
7. Step x Ratio:
8. Quality x Context:
9. Context x Ratio:
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2. Step: Increasing [e–o], [ɛ–ʌ],
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3. Quality: lax = 1, tense = -1,
   – = fewer "back" when lax
4. Context: _p = 1, _t = -1,
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Misparse 2: Model

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2. Step: Increasing [e–o], [ɛ–ʌ],
   + = more "back" as step increases
3. Quality: lax = 1, tense = -1,
   – = fewer "back" when lax
4. Context: _p = 1, _t = -1,
   + = more "back" before [p]
5. Ratio: 30:70 = 1, 50:50 = 0, 70:30 = -1;
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   – = fewer "back" as step increases when lax,
7. Step x Ratio:
8. Quality x Context:
9. Context x Ratio:
10. Quality x Context x Ratio:

Effect	Estimate	*se*	*z*	*p*
(Intercept)	1.057584	0.204428	5.173	2.30e-07
Step	0.331160	0.022154	14.948	< 2e-16
Quality	-1.187681	0.173749	-6.836	8.17e-12
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Ratio	-0.023682	0.044346	-0.534	0.5933
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Misparse 2: Model

1. "back:front" ∼ Step * Quality + Step * Ratio + Quality * Context * Ratio + (1 + Context + VowelQual + Step + Ratio | Subject)
2. Step: Increasing [e–o], [ɛ–ʌ],
   + = more "back" as step increases
3. Quality: lax = 1, tense = -1,
   – = fewer "back" when lax
4. Context: _p = 1, _t = -1,
   + = more "back" before [p]
5. Ratio: 30:70 = 1, 50:50 = 0, 70:30 = -1;
6. Step x Quality:
   – = fewer "back" as step increases when lax,
7. Step x Ratio:
   – = fewer "back" as step increases when transition is longer,
8. Quality x Context:
9. Context x Ratio:
10. Quality x Context x Ratio:

Effect	Estimate	*se*	*z*	*p*
(Intercept)	1.057584	0.204428	5.173	2.30e-07
Step	0.331160	0.022154	14.948	< 2e-16
Quality	-1.187681	0.173749	-6.836	8.17e-12
Context	1.689806	0.202223	8.356	< 2e-16
Ratio	-0.023682	0.044346	-0.534	0.5933
Step x Quality	-0.240075	0.007883	-30.454	< 2e-16
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Quality x Context	0.294180	0.031595	9.311	< 2e-16
Context x Ratio	0.099796	0.035302	2.827	0.0047
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Misparse 2: Model

1. "back:front" ∼ Step * Quality + Step * Ratio + Quality * Context * Ratio + (1 + Context + VowelQual + Step + Ratio | Subject)
2. Step: Increasing [e–o], [ɛ–ʌ],
   + = more "back" as step increases
3. Quality: lax = 1, tense = -1,
   – = fewer "back" when lax
4. Context: _p = 1, _t = -1,
   + = more "back" before [p]
5. Ratio: 30:70 = 1, 50:50 = 0, 70:30 = -1;
6. Step x Quality:
   – = fewer "back" as step increases when lax,
7. Step x Ratio:
   – = fewer "back" as step increases when transition is longer,
8. Quality x Context:
   + = more "back" when lax before [p],
9. Context x Ratio:
10. Quality x Context x Ratio:

Effect	Estimate	*se*	*z*	*p*
(Intercept)	1.057584	0.204428	5.173	2.30e-07
Step	0.331160	0.022154	14.948	< 2e-16
Quality	-1.187681	0.173749	-6.836	8.17e-12
Context	1.689806	0.202223	8.356	< 2e-16
Ratio	-0.023682	0.044346	-0.534	0.5933
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Quality x Context	0.294180	0.031595	9.311	< 2e-16
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Misparse 2: Model

1. "back:front" ∼ Step * Quality + Step * Ratio + Quality * Context * Ratio + (1 + Context + VowelQual + Step + Ratio | Subject)
2. Step: Increasing [e–o], [ɛ–ʌ],
   + = more "back" as step increases
3. Quality: lax = 1, tense = -1,
   – = fewer "back" when lax
4. Context: _p = 1, _t = -1,
   + = more "back" before [p]
5. Ratio: 30:70 = 1, 50:50 = 0, 70:30 = -1;
6. Step x Quality:
   – = fewer "back" as step increases when lax,
7. Step x Ratio:
   – = fewer "back" as step increases when transition is longer,
8. Quality x Context:
   + = more "back" when lax before [p],
9. Context x Ratio:
   + = more "back" before [p] when transition is longer,
10. Quality x Context x Ratio:

Effect	Estimate	*se*	*z*	*p*
(Intercept)	1.057584	0.204428	5.173	2.30e-07
Step	0.331160	0.022154	14.948	< 2e-16
Quality	-1.187681	0.173749	-6.836	8.17e-12
Context	1.689806	0.202223	8.356	< 2e-16
Ratio	-0.023682	0.044346	-0.534	0.5933
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Quality x Context x Ratio	0.087189	0.033911	2.571	0.0101

Misparse 2: Model

1. "back:front" ∼ Step * Quality + Step * Ratio + Quality * Context * Ratio + (1 + Context + VowelQual + Step + Ratio | Subject)
2. Step: Increasing [e–o], [ɛ–ʌ],
   + = more "back" as step increases
3. Quality: lax = 1, tense = -1,
   – = fewer "back" when lax
4. Context: _p = 1, _t = -1,
   + = more "back" before [p]
5. Ratio: 30:70 = 1, 50:50 = 0, 70:30 = -1;
6. Step x Quality:
   – = fewer "back" as step increases when lax,
7. Step x Ratio:
   – = fewer "back" as step increases when transition is longer,
8. Quality x Context:
   + = more "back" when lax before [p],
9. Context x Ratio:
   + = more "back" before [p] when transition is longer,
10. Quality x Context x Ratio:
    + = more "back" when lax before [p] when transition is longer.

Effect	Estimate	*se*	*z*	*p*
(Intercept)	1.057584	0.204428	5.173	2.30e-07
Step	0.331160	0.022154	14.948	< 2e-16
Quality	-1.187681	0.173749	-6.836	8.17e-12
Context	1.689806	0.202223	8.356	< 2e-16
Ratio	-0.023682	0.044346	-0.534	0.5933
Step x Quality	-0.240075	0.007883	-30.454	< 2e-16
Step x Ratio	-0.042858	0.006914	-6.199	5.69e-10
Quality x Context	0.294180	0.031595	9.311	< 2e-16
Context x Ratio	0.099796	0.035302	2.827	0.0047
Quality x Context x Ratio	0.087189	0.033911	2.571	0.0101

Misparse 2: Summary

1. More misparsing of:
   a. Longer transitions,
   b. Lax than tense vowels,
   c. Lax vowels with longer transitions;
2. Confirms the predictions of the Misparse Hypothesis.

Does response time matter?

If assimilation is misparsing acoustic properties of a later sound as belonging to an earlier one, would slower responses show less assimilation?

Does response time matter?

1. "back:front" ~ Step*Quality*logRT + Step*Context*logRT + Step*Ratio*logRT + Quality*Context*logRT + Quality*Ratio*logRT + Context*Ratio*logRT + (1 + ... | Subject))
2. Fewer "back" as step increases when slower,
3. More "back" when lax and slower,
4. Fewer "back" before [p] when slower,
5. More "back" with longer transition when slower,
6. More "back" as step increases when lax and slower,
7. More "back" as step increases before [p] when slower.

Effect	Estimate	*se*	*z*	*p*
(Intercept)	1.1167645	0.2064800	5.409	6.35e-08
Step	0.3331991	0.0221863	15.018	< 2e-16
Quality	-1.2602472	0.1780755	-7.077	1.47e-12
Context	1.7523571	0.2101737	8.338	< 2e-16
Ratio	-0.0292102	0.0475631	-0.614	0.539126
logRT	-0.4091419	0.1762738	-2.321	0.020284
Step x logRT	-0.0401607	0.0215864	-1.860	0.062820
Quality x logRT	0.4786202	0.1061471	4.509	6.51e-06
Context x logRT	-0.6482163	0.0957924	-6.767	1.32e-11
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Does response time matter?

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Quality	-1.2602472	0.1780755	-7.077	1.47e-12
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Conclusions

1. "Misparsing" associates material between two sounds to the earlier (left hand) one,
2. Extent of misparsing depends directly on amount of intermediate or transitional material,
3. Default boundary placement is later,
4. Parallels Late Closure preference in syntactic structure parsing (Frazier, 1979),
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