



**BIASED LEARNING OF
PHONOLOGICAL ALTERNATIONS BY
12-MONTH-OLD INFANTS**

James White & Megha Sundara

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PHONOLOGICAL ALTERNATIONS

- **Phonological alternation**: phonemes have **variant surface forms** depending on context.
 - American English: *pat* [pæt̚] ~ *patting* [pæɾɪŋ]
- Infants must learn the alternations of their native language during the language acquisition process.
- We know that they are at least able to do so by 12 months of age.¹
- How do they learn these alternations?

BACKGROUND

- We still know little about how infants learn phonological alternations.
- We know that **statistical learning** is a powerful tool for the infant during the first year of life, used for:
 - Discriminating speech sounds¹
 - Phonotactic learning²
 - Word segmentation³
 - Presumably phonological alternations??

1. Maye et al., 2002; Anderson et al., 2003

2. Chambers et al., 2003

3. Saffran et al., 2006

BACKGROUND

- Is statistical learning the only component?
 - Are infants just looking for **complementary distributions**?
- Unlikely:
 - [h] and [ŋ] happen to be in perfect complementary distribution in English.
 - But we probably don't want to say they are alternating variants of the same category.¹
- Is this learning constrained in some way?

1. see Peperkamp et al., 2006 for similar examples

BACKGROUND

- Previous work has shown that phonological learning is constrained by biases:
 - People find some patterns harder to learn (or less plausible) than others.¹
 - Sometimes people make assumptions during learning that extend beyond what is available in their input.²
- Most of the work on biases in phonological learning has been conducted with adults.
 - We still know relatively little about biases in infant phonological learning.³
- We need a test case.

1. Moreton, 2008; Hayes et al., 2009; Skoruppa et al., 2011; Hayes & White, in press

2. Wilson, 2006; Finley & Badecker, 2008

3. But see Seidl & Buckley, 2005; Jusczyk et al., 2002.

TEST CASE: SALTATORY ALTERNATIONS

- What is a **saltatory alternation**?
 - Phonological alternation that “jumps over” a non-alternating, **intermediate** sound.¹
 - From Latin *saltus* ‘leap’. Also called “leapfrogging.”²
 - Example from Campidanian Sardinian³:
 - $p \rightarrow \beta / V _$, but $/b/$ remains unchanged
- [pãi] → [s:u βãi] ‘the bread’

[bĩu] → [s:u bĩu] ‘the wine’
- This is a productive process that happens at other places of articulation as well.

SALTATORY ALTERNATION

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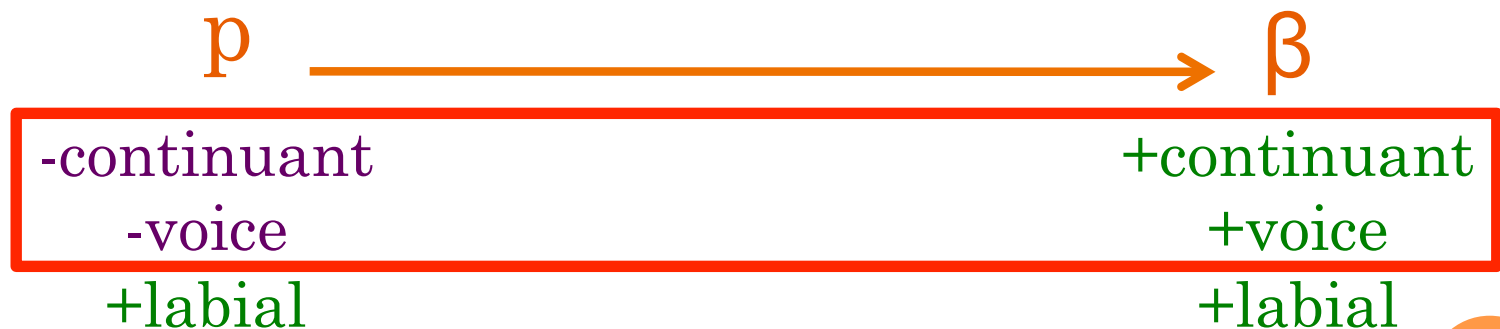
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2 feature
changes



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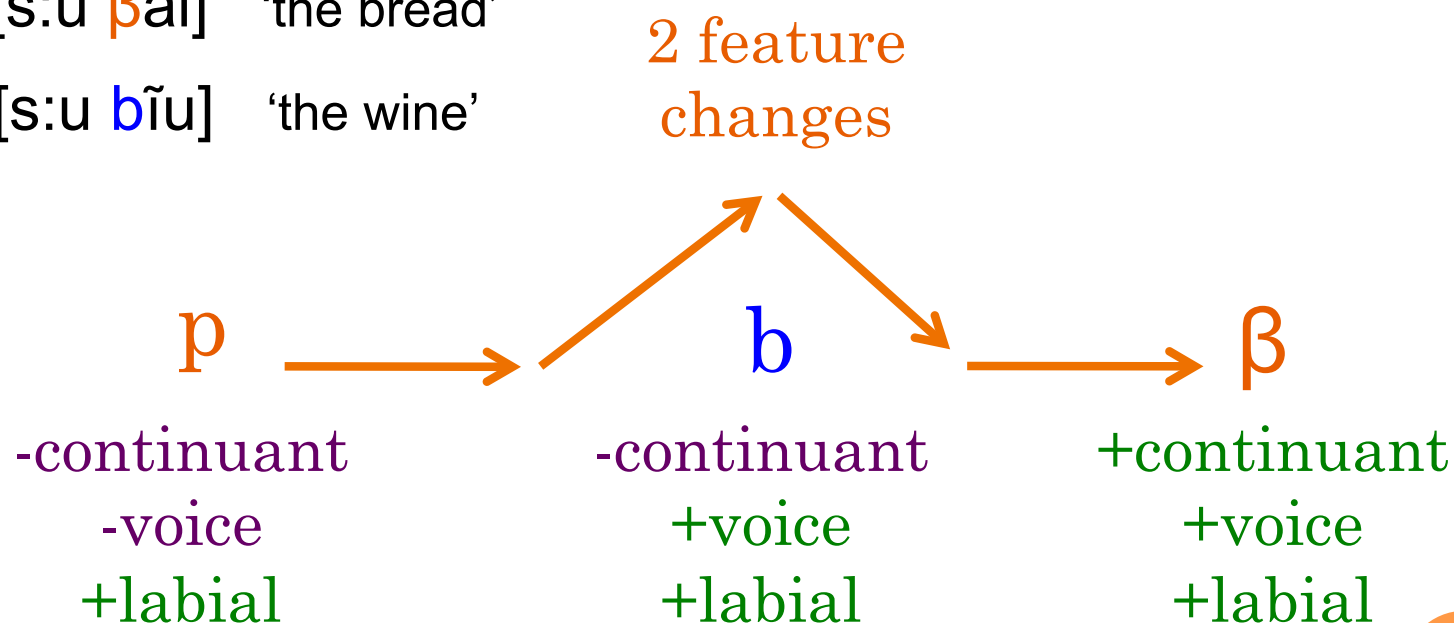


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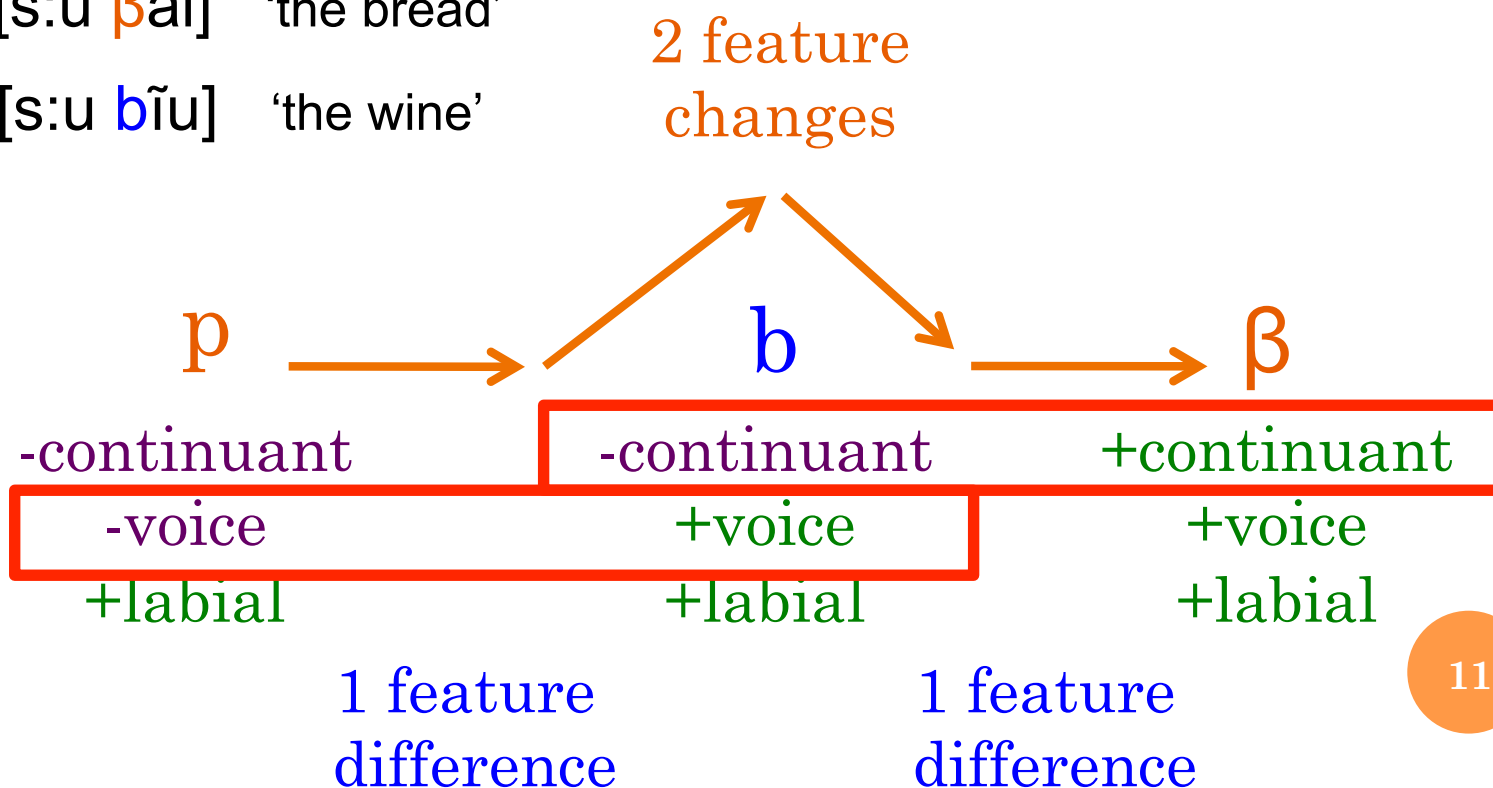


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WHY FOCUS ON SALTATORY ALTERNATIONS?

- Researchers have long noted that phonological alternations between dissimilar sounds are less common cross-linguistically.¹
- Alternations usually follow the principle of **minimal modification** – if you are going to alternate, you should make the smallest change possible.²

SALTATORY ALTERNATIONS = EXCESSIVE MODIFICATION

- Saltatory alternations are striking counterexamples to the principle of **minimal modification**:
 - Involve dissimilar sounds (multiple feature changes).
 - They represent **excessive modification** – other possibilities exist that would require less extreme changes.
 - **Intuitively**: Why change $p \rightarrow \beta$ when [b] is closer to [p] and legal?
-or-
If you go to the trouble of changing $p \rightarrow \beta$, why not also change $b \rightarrow \beta$?
- Due to this characteristic, some phonological theories predict saltatory alternations should not exist at all.¹

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 - Due to this characteristic, some phonological theories predict saltatory alternations should not exist at all.¹
- If alternations between dissimilar sounds are less common (in general), **saltatory** alternations appear to be **especially uncommon**.

ADULTS ARE BIASED AGAINST THEM

- Adults are biased against saltatory alternations when learning an artificial language.¹
 - When learning **potentially saltatory alternations**, they assume intermediate sounds change without evidence in the input.
 - E.g., **Learn**: $p \rightarrow v$, **Assume**: $b \rightarrow v$
 - Even with explicit evidence, they find saltatory alternations harder to learn.

MAIN POINTS OF TODAY'S TALK

- 12-month-old infants, like adults, exhibit a bias against saltatory alternations.
- One plausible basis for such behavior is a bias based on the similarity of the alternating sounds.

EXPERIMENT OVERVIEW

- White, Peperkamp, Kirk, & Morgan (2008):

- Train:

p → b -or- f → v

- Test:

p → b -and- f → v

- Result:

Differentiated test items depending on training.

EXPERIMENT OVERVIEW

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p → b -or- f → v

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p → b -and- f → v

- Result:

Differentiated test items depending on training.

- Current study:

- Train

p → v -or- t → z

- Test:

b → v -and- d → z

- Prediction:

If infants are like adults, differentiate test items depending on training.

METHOD

- Visual Fixation procedure¹



1. Werker et al., 1998

METHOD

- Participants:
 - 36 twelve-month-olds (18 per condition)
 - Monolingual English input

METHOD

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 - 36 twelve-month-olds (18 per condition)
 - Monolingual English input
- 2 phases: Exposure phase & Test phase

EXPOSURE PHASE

- Repeating phrases of function word + content word
 - E.g., *na voli...rom timu...rom zimu...rom panu...na timu...na voli...*
 - 2 function words (*na* or *rom*); 8 content word pairs
- 3 trials, 45 sec each (total of 135 sec)
- Not infant controlled
- 2 conditions: **Potentially Saltatory** and **Control**
- 2 exposure groups – Labials Alternating or Coronals Alternating (half randomly assigned to each)

EXPOSURE GROUPS

Potentially Saltatory

Labials Alternating		Coronals Alternating	
<i>rom poli</i>	<i>na voli</i>	<i>rom poli</i>	<i>rom voli</i>
<i>rom poli</i>	<i>na voli</i>	<i>na poli</i>	<i>na voli</i>
<i>rom timu</i>	<i>rom zimu</i>	<i>rom timu</i>	<i>na zimu</i>
<i>na timu</i>	<i>na zimu</i>	<i>rom timu</i>	<i>na zimu</i>

EXPOSURE GROUPS

Potentially Saltatory

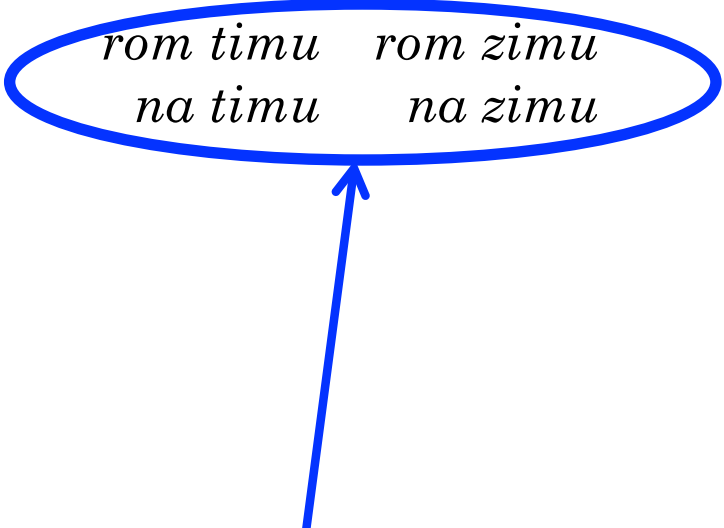
Labials Alternating		Coronals Alternating	
<i>rom poli</i>	<i>na voli</i>	<i>rom poli</i>	<i>rom voli</i>
<i>rom poli</i>	<i>na voli</i>	<i>na poli</i>	<i>na voli</i>
<i>rom timu</i>	<i>rom zimu</i>	<i>rom timu</i>	<i>na zimu</i>
<i>na timu</i>	<i>na zimu</i>	<i>rom timu</i>	<i>na zimu</i>

Alternating based on context: [p] only after *rom*
[v] only after *na*

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<i>na timu</i>	<i>na zimu</i>	<i>rom timu</i>	<i>na zimu</i>



Contrastive: [t] and [z] after both *rom* and *na*.

EXPOSURE GROUPS

Potentially Saltatory

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<i>rom poli</i>	<i>na voli</i>	<i>rom poli</i>	<i>rom voli</i>
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<i>rom timu</i>	<i>rom zimu</i>	<i>rom timu</i>	<i>na zimu</i>
<i>na timu</i>	<i>na zimu</i>	<i>rom timu</i>	<i>na zimu</i>



Opposite pattern in this group.

EXPOSURE GROUPS

Potentially Saltatory

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<i>na timu</i>	<i>na zimu</i>	<i>rom timu</i>	<i>na zimu</i>



Control

Labials Alternating		Coronals Alternating	
<i>rom boli</i>	<i>na voli</i>	<i>rom boli</i>	<i>rom voli</i>
<i>rom boli</i>	<i>na voli</i>	<i>na boli</i>	<i>na voli</i>
<i>rom dimu</i>	<i>rom zimu</i>	<i>rom dimu</i>	<i>na zimu</i>
<i>na dimu</i>	<i>na zimu</i>	<i>rom dimu</i>	<i>na zimu</i>

TEST PHASE

- Each trial = One novel pair of words repeated without *na* or *rom*
 - Thus, context no longer available at test – infants must map alternating forms onto same underlying forms.
- Within a given condition, infants received same test trials, regardless of Exposure Group
 - Potentially Saltatory: (trained on [p] ~ [v] or [t] ~ [z])
 - *buni/vuni, bagu/vagu, dilu/zilu, dari/zari*
 - Control: (trained on [b] ~ [v] or [d] ~ [z])
 - *puni/vuni, pagu/vagu, tilu/zilu, tari/zari*
 - Note: Half labials, half coronals
- Infant controlled
- 3 blocks, 4 trials each (12 total test trials)
- Order of test trials was counterbalanced across infants



EXPERIMENT OVERVIEW

■ training ■ testing

Potentially Saltatory

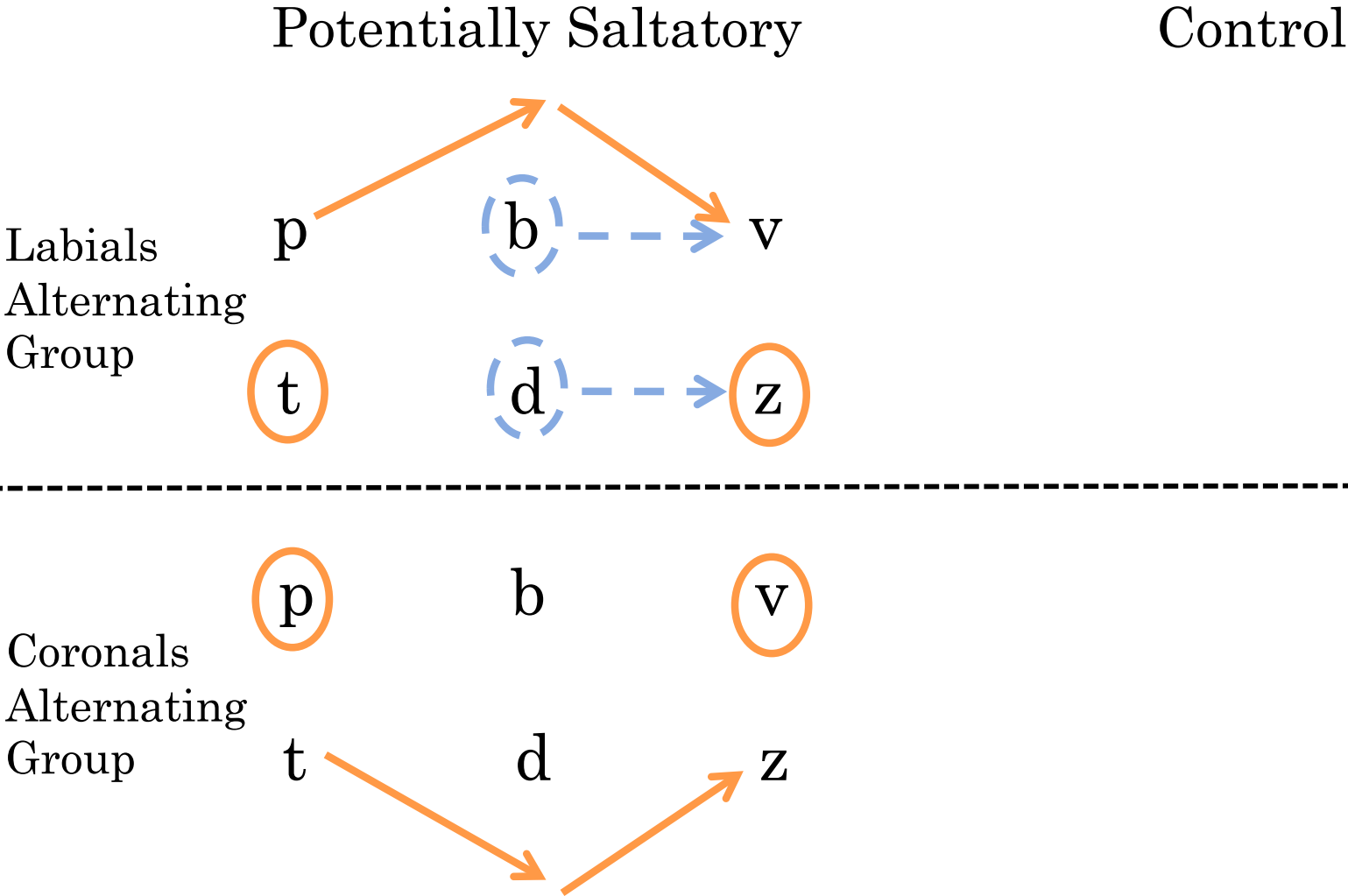
Control

Labials	p	b	v
Alternating Group	t	d	z

Coronals
Alternating
Group

EXPERIMENT OVERVIEW

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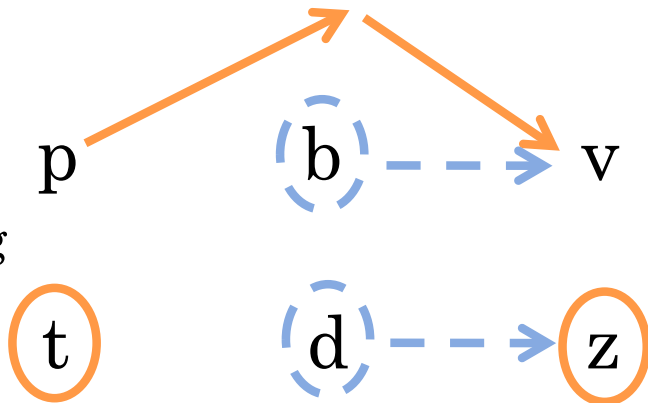
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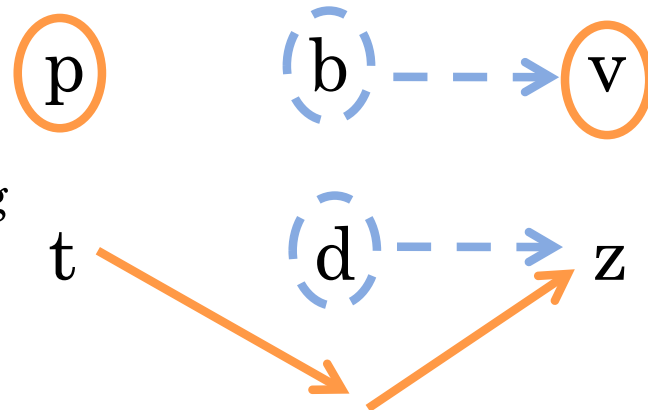
Potentially Saltatory

Control

Labials
Alternating
Group

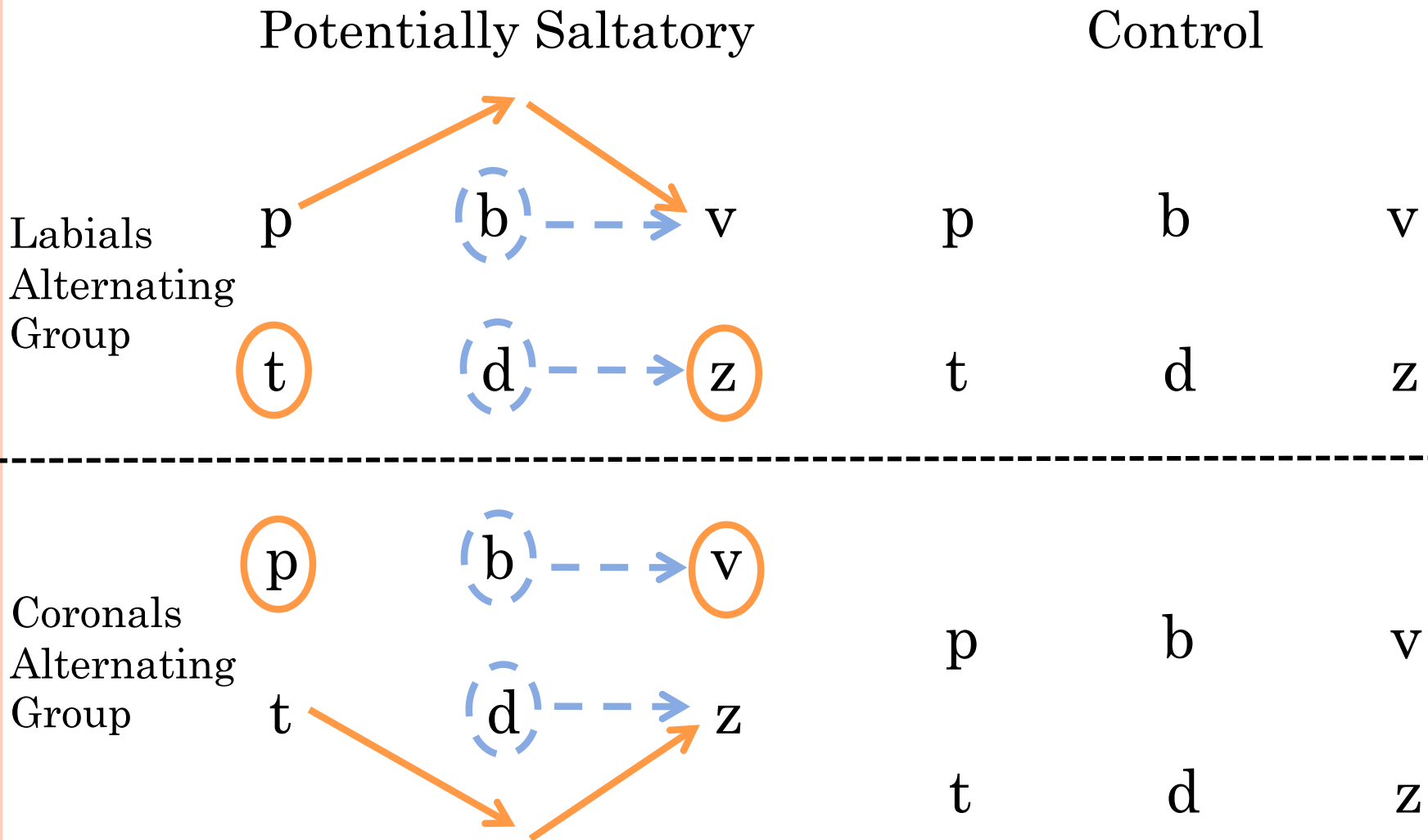


Coronals
Alternating
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EXPERIMENT OVERVIEW

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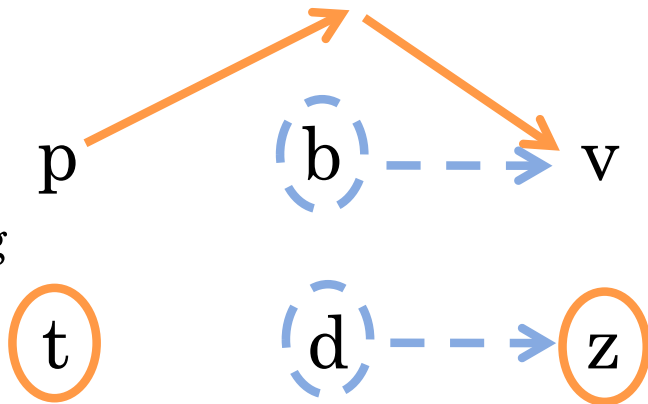


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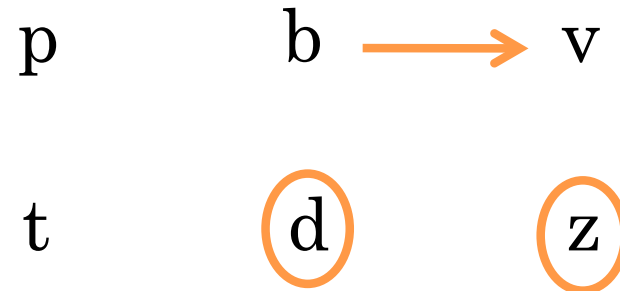
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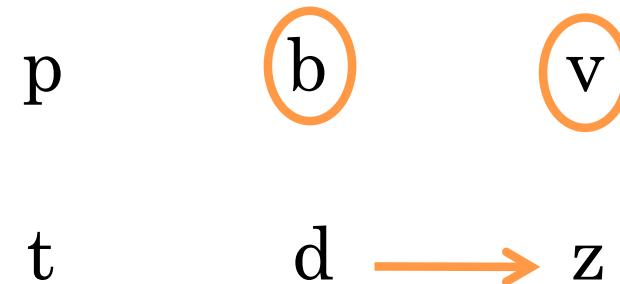
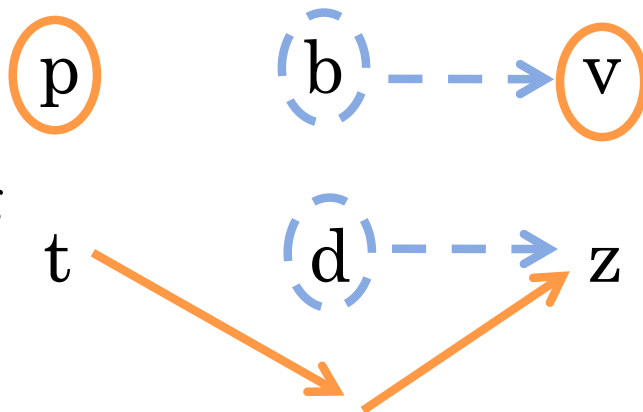
Labials
Alternating
Group



Control



Coronals
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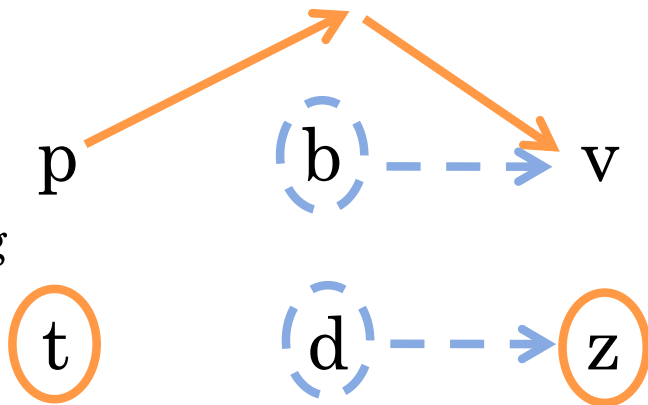


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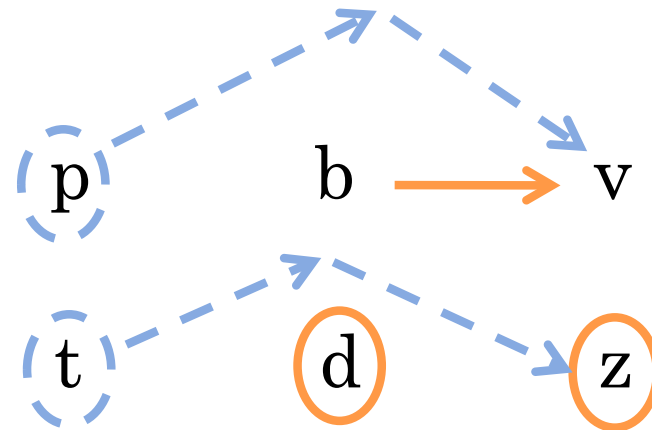
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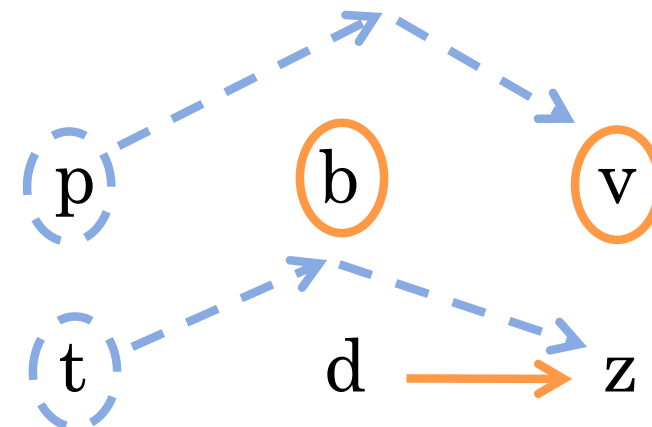
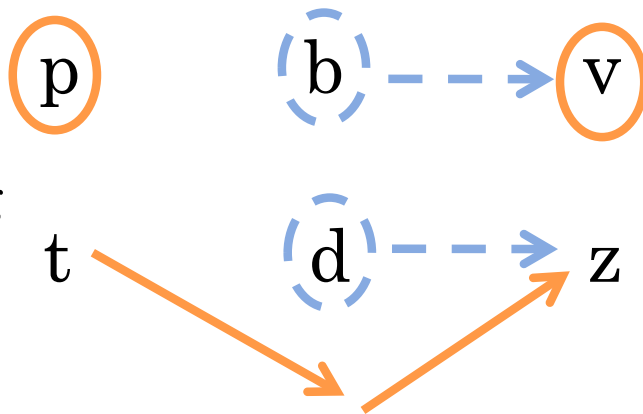
Labials
Alternating
Group



Control



Coronals
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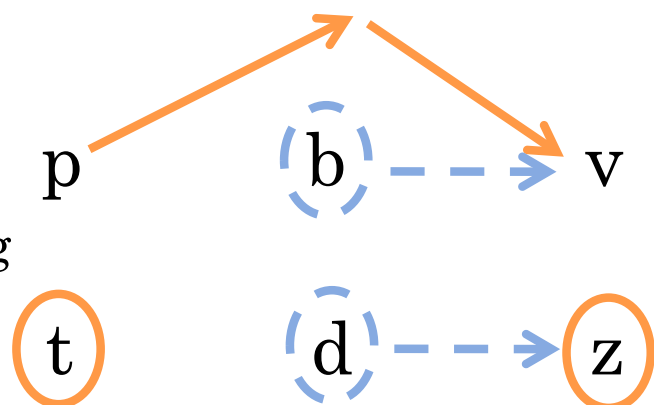
PREDICTIONS

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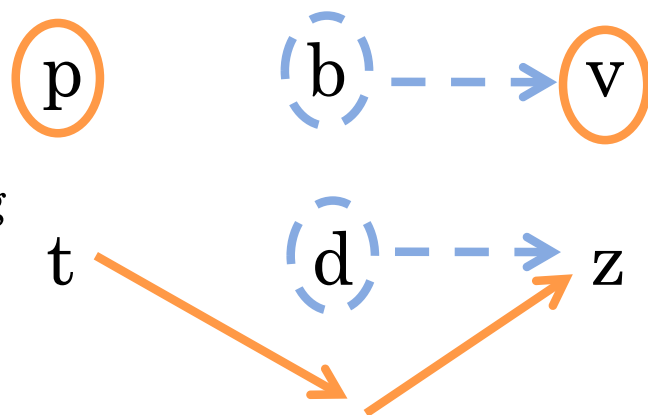
Potentially Saltatory

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Labials
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Coronals
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[b] is intermediate between trained alternation;
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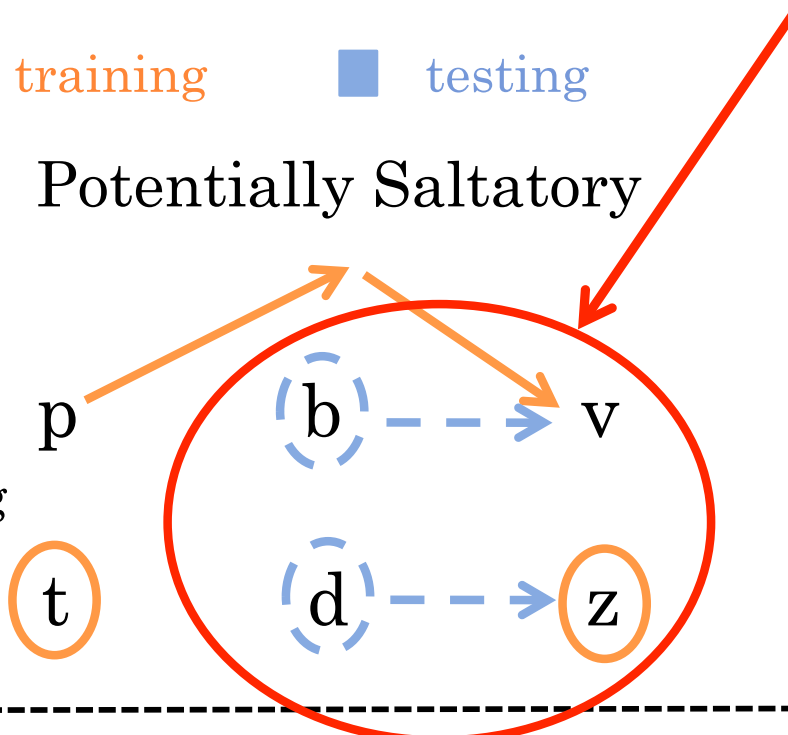
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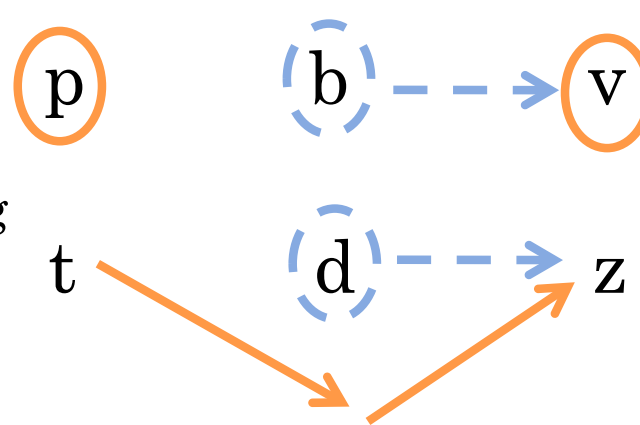
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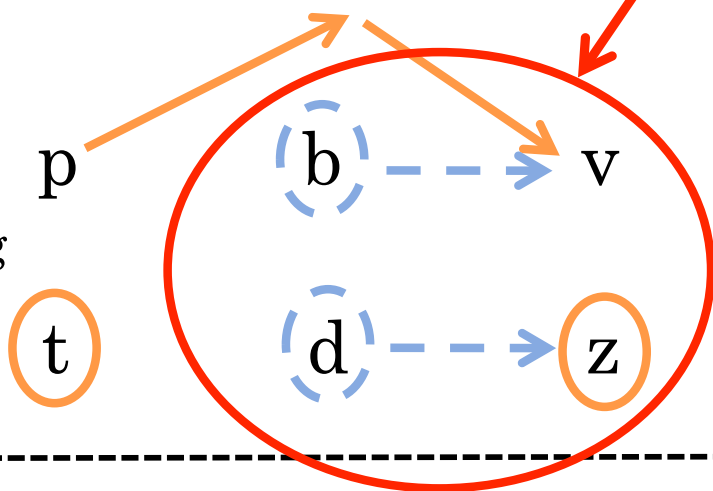
[b] and [d] should be treated DIFFERENTLY!!!

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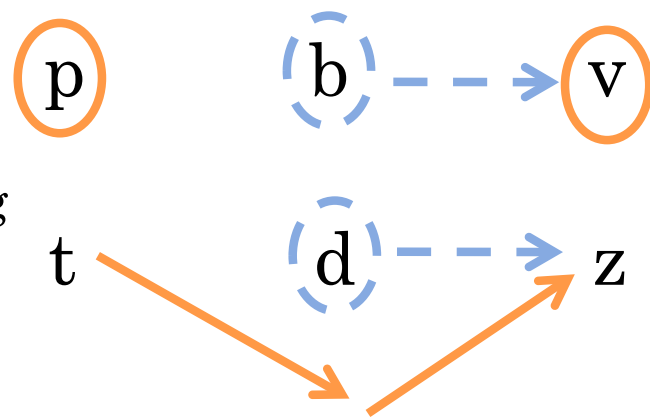
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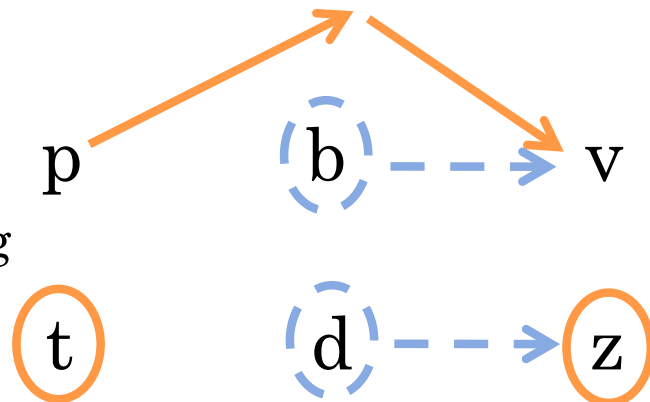
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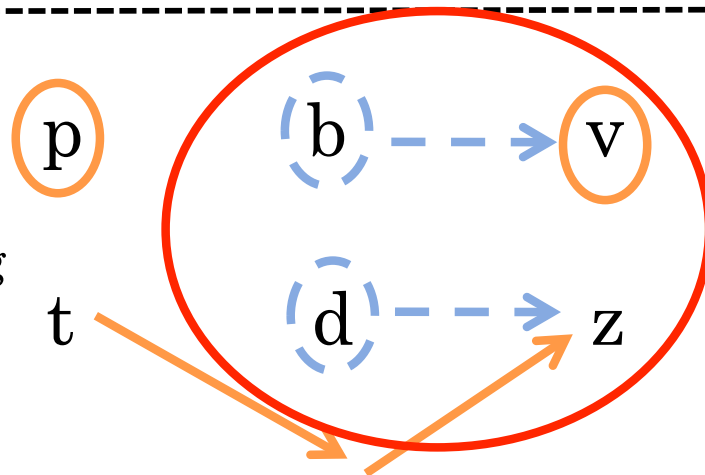
Potentially Saltatory

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Alternating
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Coronals
Alternating
Group



These should also be treated differently, but in the opposite way!

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[d] is not.

PREDICTIONS

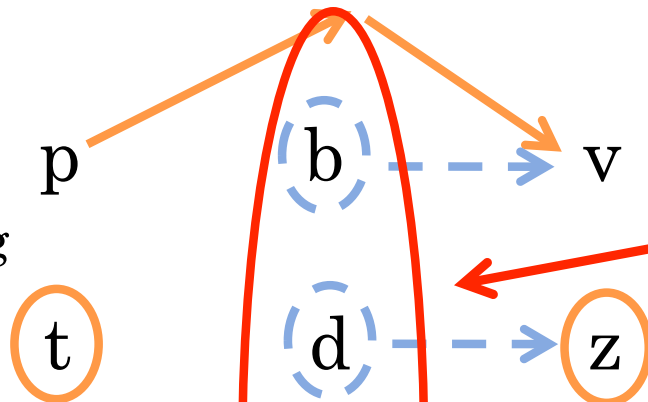
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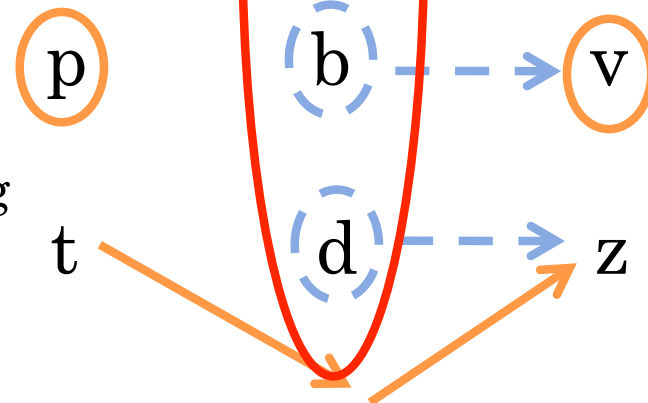
Control

Labials
Alternating
Group



Same test stimuli, but which sound is intermediate between the alternation depends on exposure.
→ Rules out item effects and effects based on specific sounds.

Coronals
Alternating
Group



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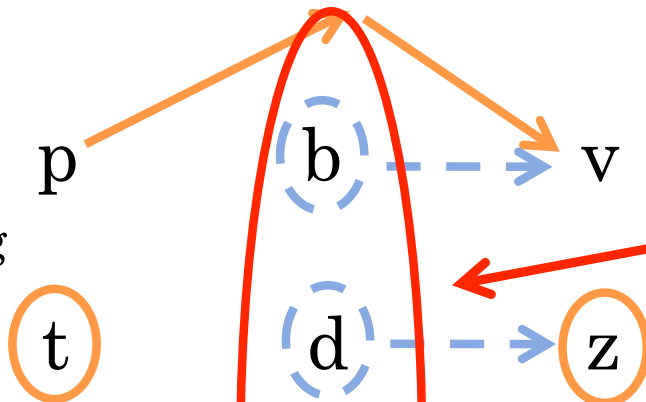
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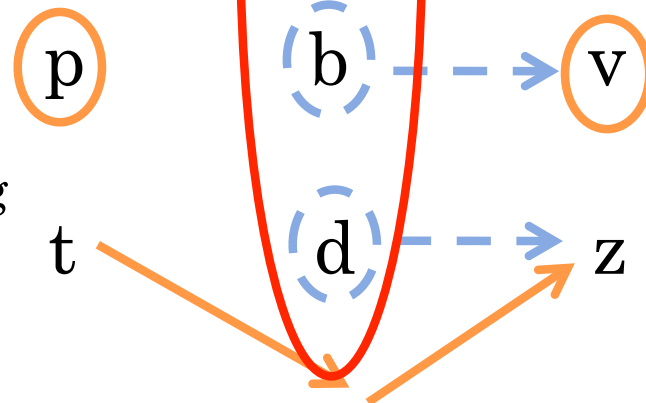
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Coronals
Alternating
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In fact: no significant differences found between exposure groups – so they are collapsed in the following results.

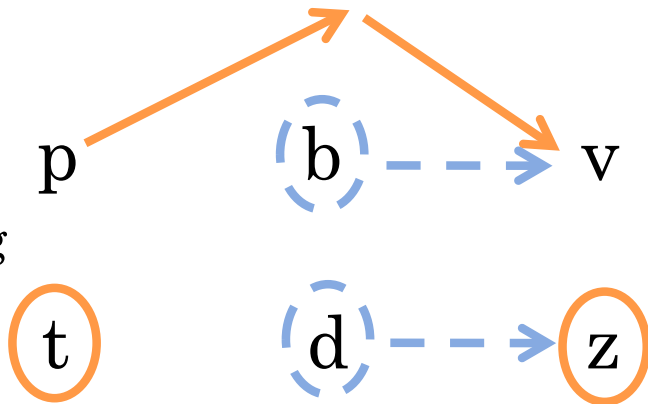
PREDICTIONS

Neither sound intermediate between alternating sounds. No differences expected.

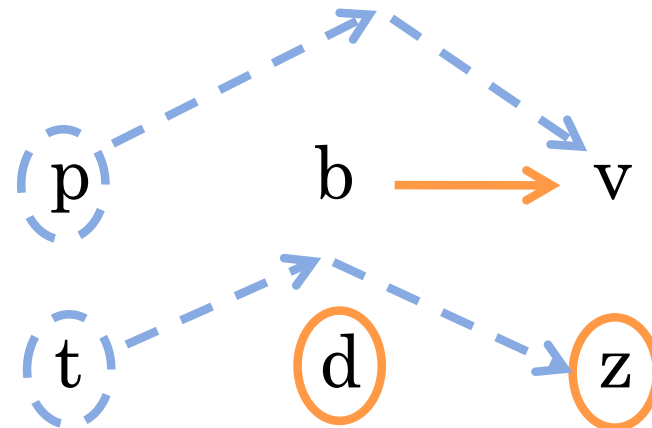
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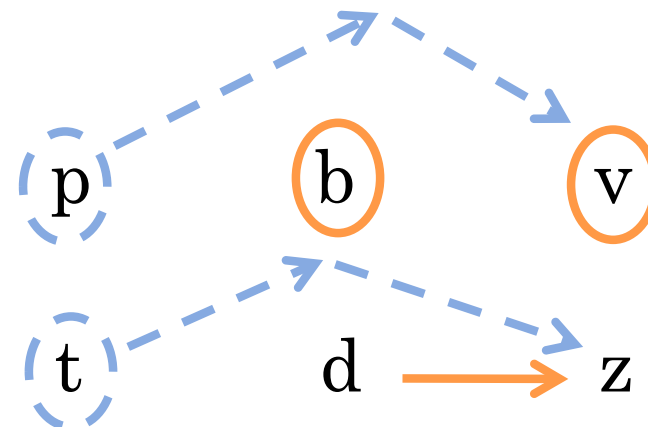
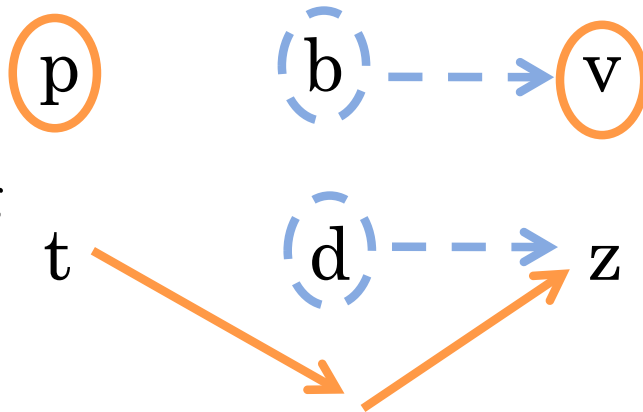
Labials
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Control



Coronals
Alternating
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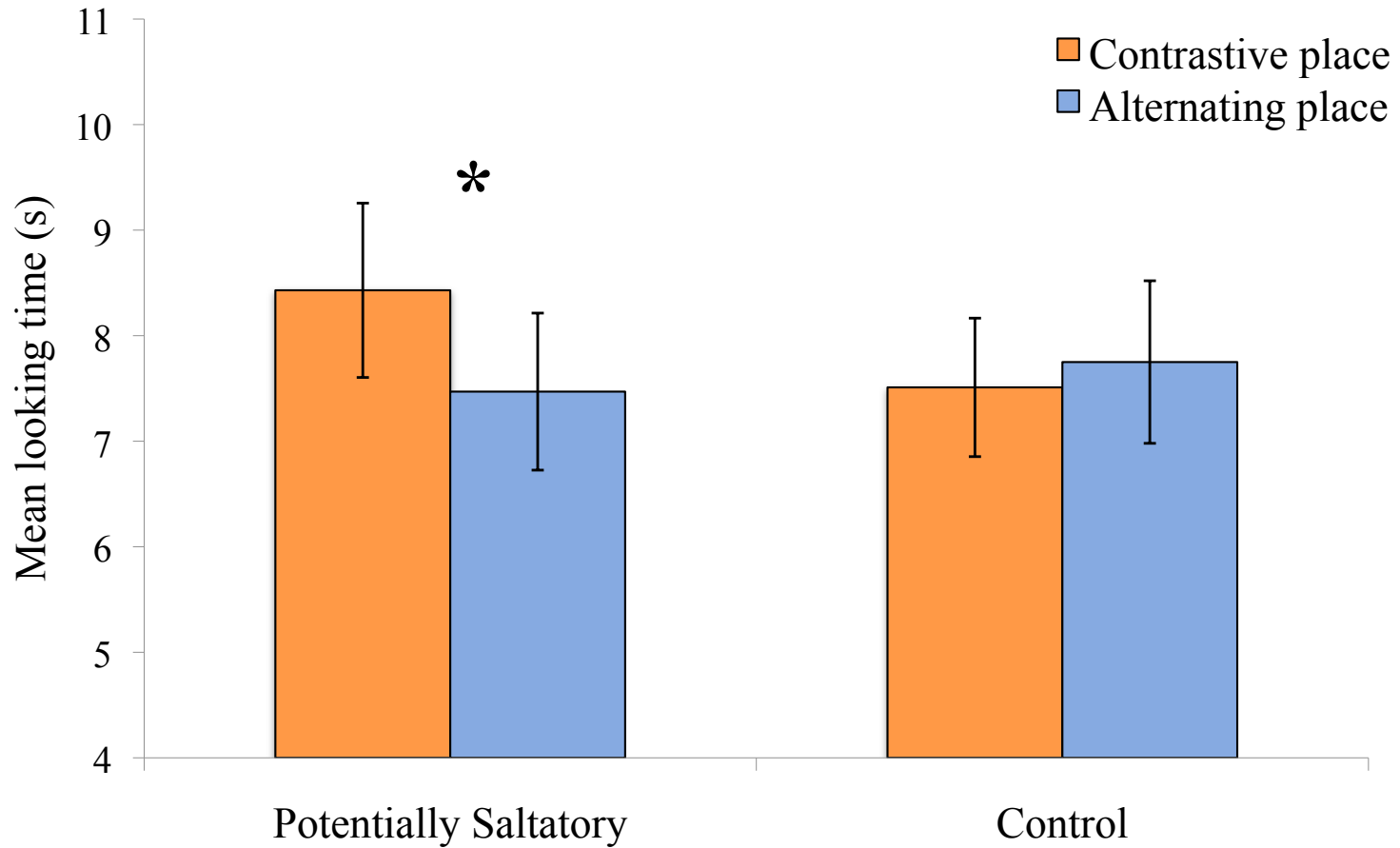
SUMMARY OF PREDICTIONS

- Potentially Saltatory condition
 - Difference between Alternating place of articulation and Contrastive place of articulation.
 - Recall: the test items included in each of these comparison groups is different depending on exposure.

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- Control condition
 - No difference.

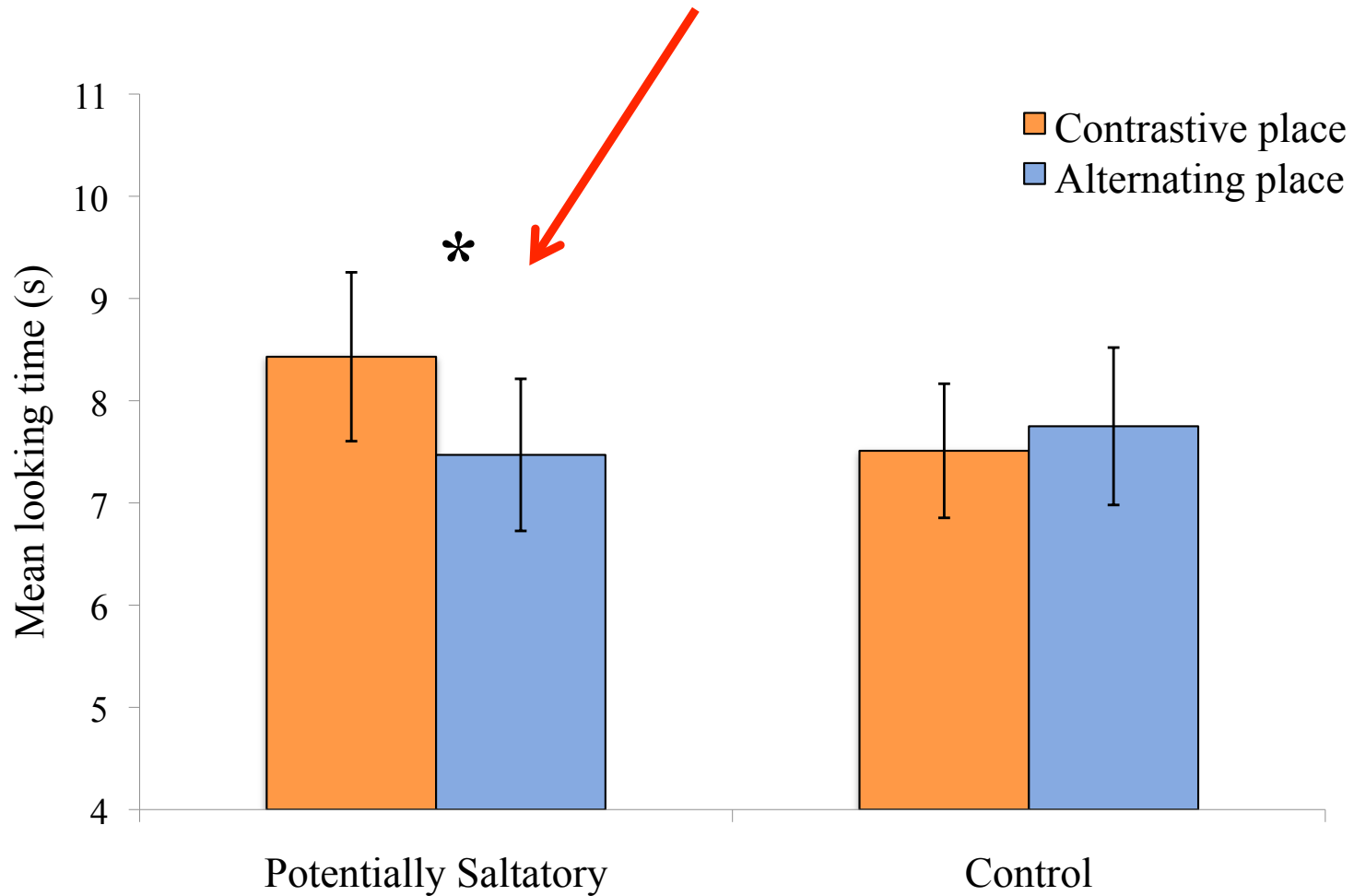
RESULTS



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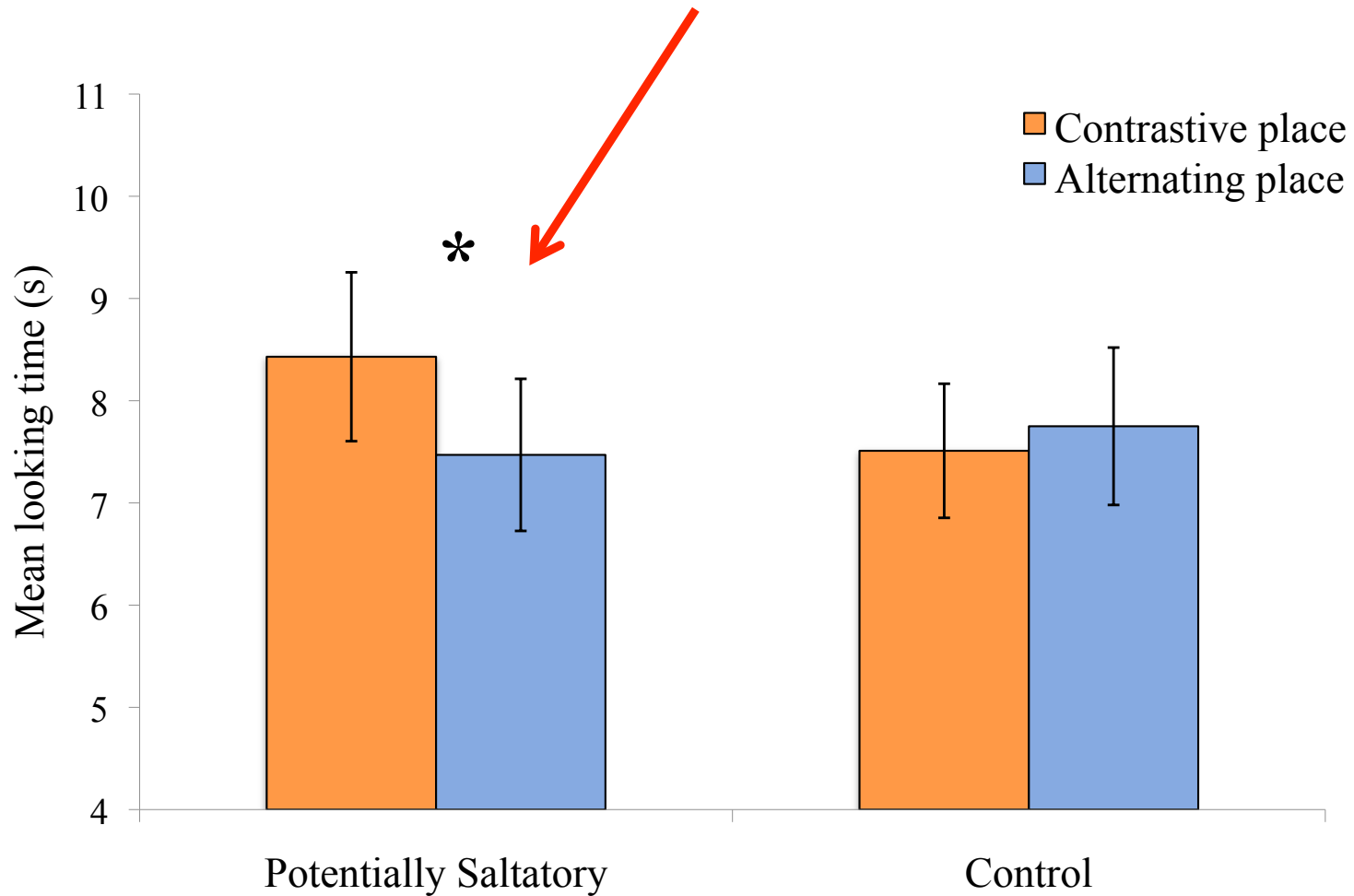
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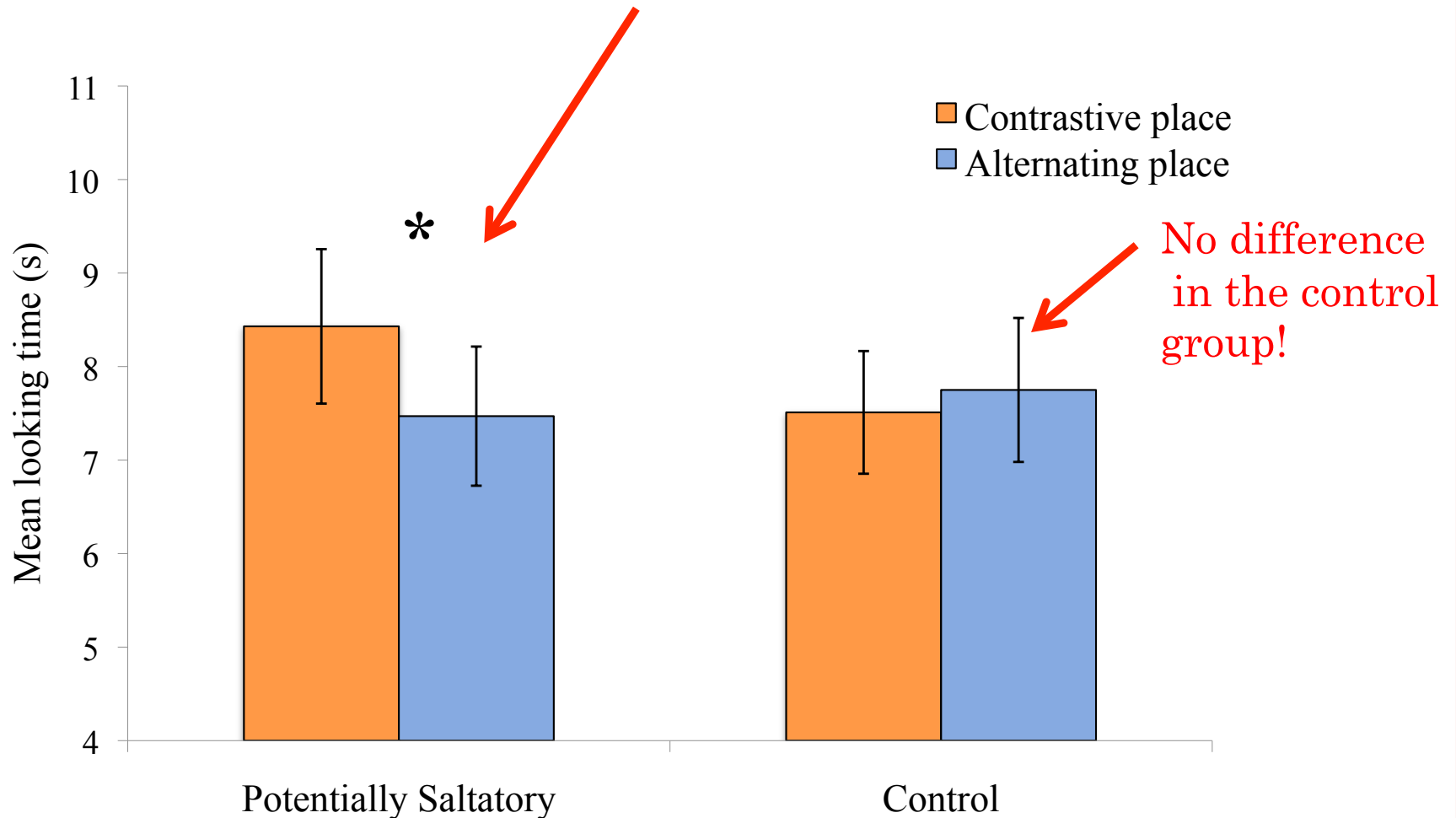


14/18 infants
showing pattern

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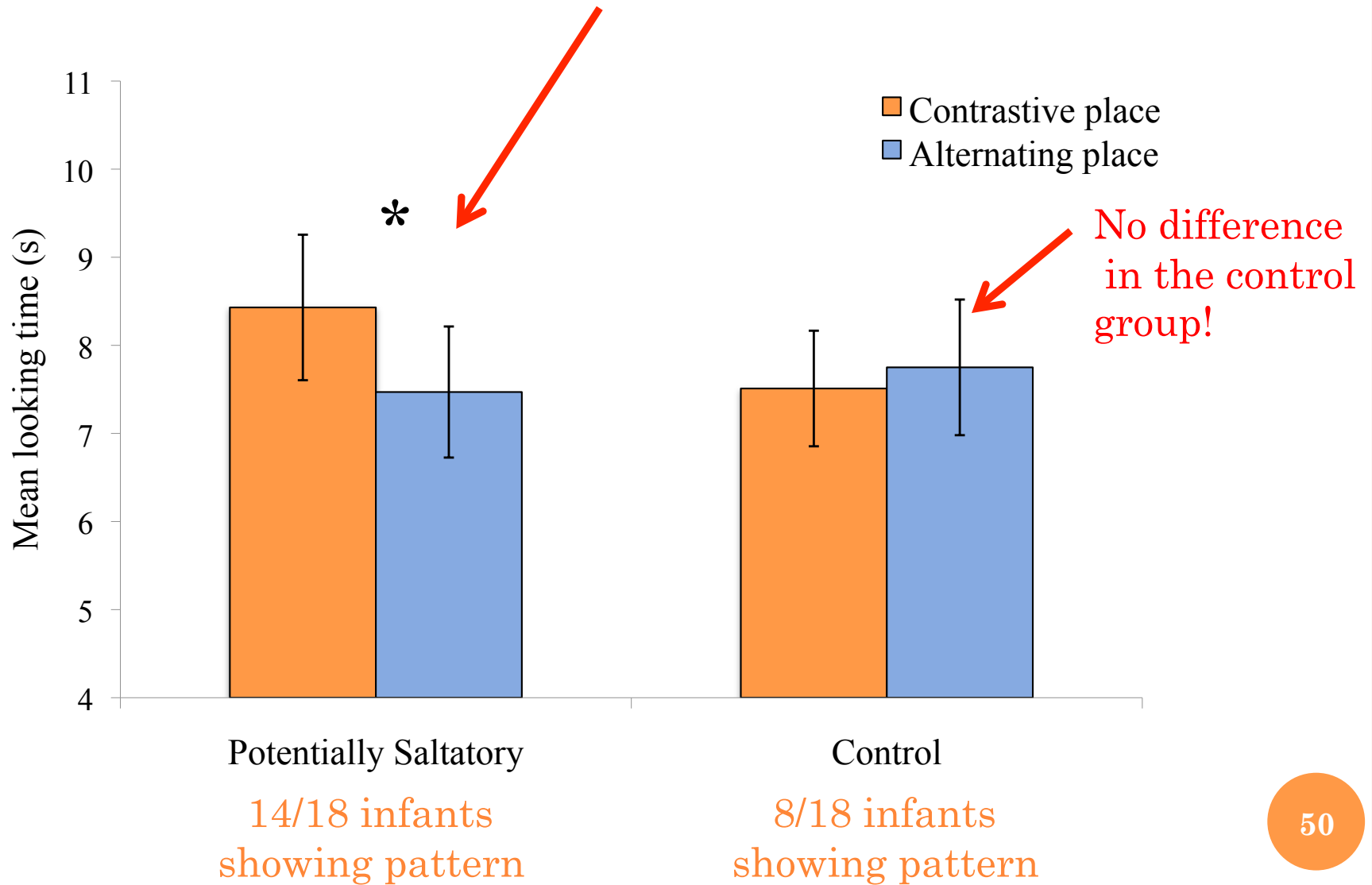


14/18 infants
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RESULTS

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DISCUSSION

- Difference between Contrastive and Alternating place of articulation, but only in the Potentially Saltatory case, as predicted.

- Bottom line:

Difference in the Potentially Saltatory case but not in the Control case

=

Infants treated the saltatory alternations differently than the non-saltatory ones.

DISCUSSION

- Infant looking time was **shorter** when sounds were intermediate between **alternating sounds** than when intermediate between contrastive sounds.
- Why do we see this behavior?
 - Plausible explanation:

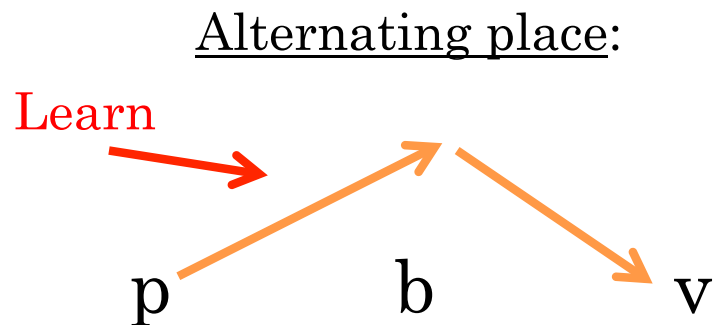
Alternating place:

p b v

Contrastive place:

DISCUSSION

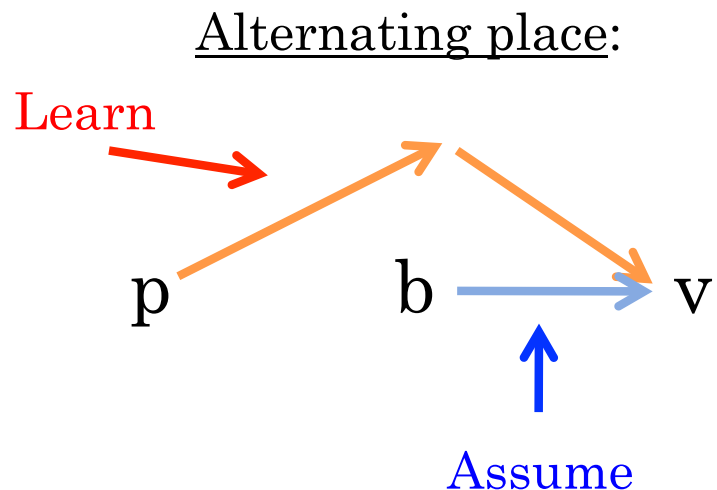
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Contrastive place:

DISCUSSION

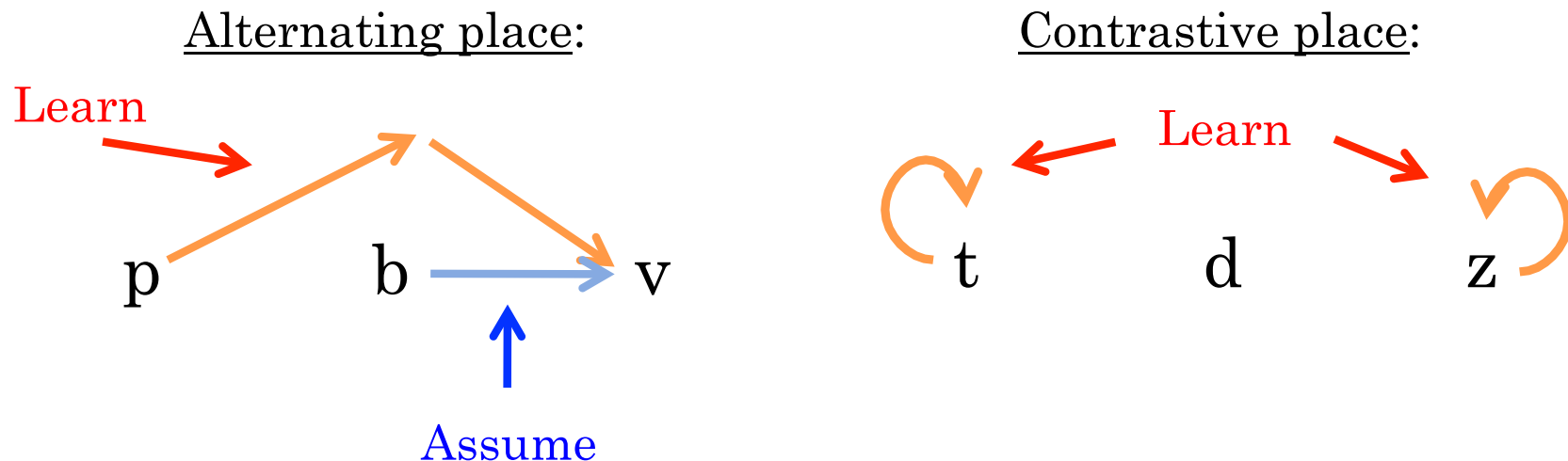
- Infant looking time was **shorter** when sounds were intermediate between **alternating sounds** than when intermediate between contrastive sounds.
- Why do we see this behavior?
 - Plausible explanation:



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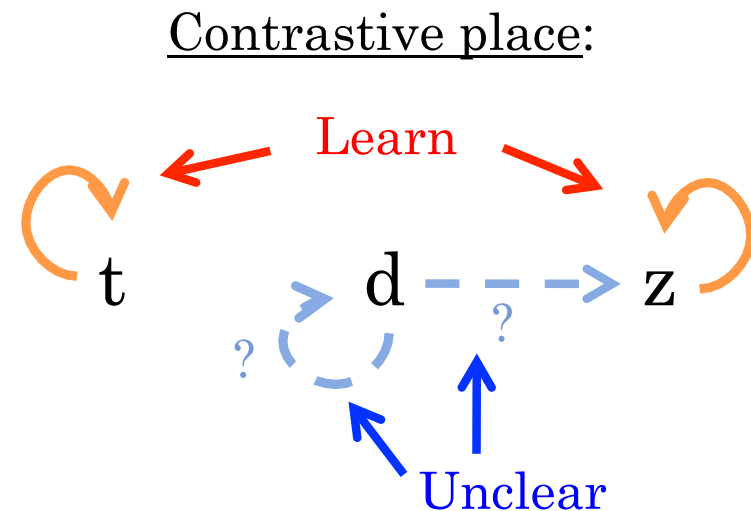
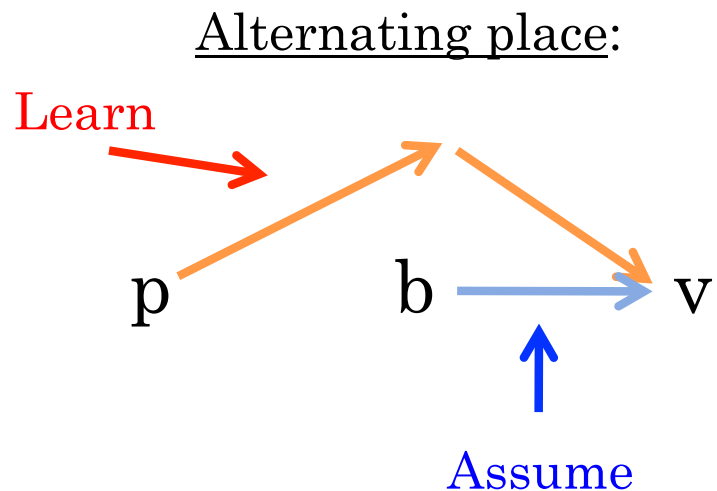
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- If dissimilar sounds alternate, 12-month-olds assume that more similar sounds are likely to alternate as well.
- By doing so, they avoid having a saltatory alternation.
- What is the source of this anti-saltation behavior?

DISCUSSION

- Conjecture: Anti-saltation preference is due to a bias based on the principle of **minimal modification**:
 - Learners are tacitly aware of the relative perceptual similarity between pairs of sounds, based on experience (Steriade's P-map).¹
 - **Minimal modification bias**: Alternations between perceptually dissimilar sounds considered less likely than those between more similar sounds.
 - Modeling the acquisition of alternations with a prior (i.e., soft bias) based on this principle does a good job of predicting the anti-saltation effect in adults.²

CONCLUSIONS

- 12-month-old infants learn novel alternations in a biased way.
 - Like adults, they apparently assume alternations will not be saltatory.
- This study provides evidence that the anti-saltation bias seen in adults¹ is also active during child language acquisition.
- A plausible basis for the anti-saltation bias is a more general bias that prefers alternations with minimal modification.

THANK YOU

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REFERENCES