The learnability of unboundedly non-myopic patterns

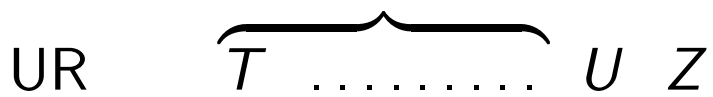
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UCLA

2026 Rutgers Subregular Morphophonology Workshop



What information is relevant to an undergoer?



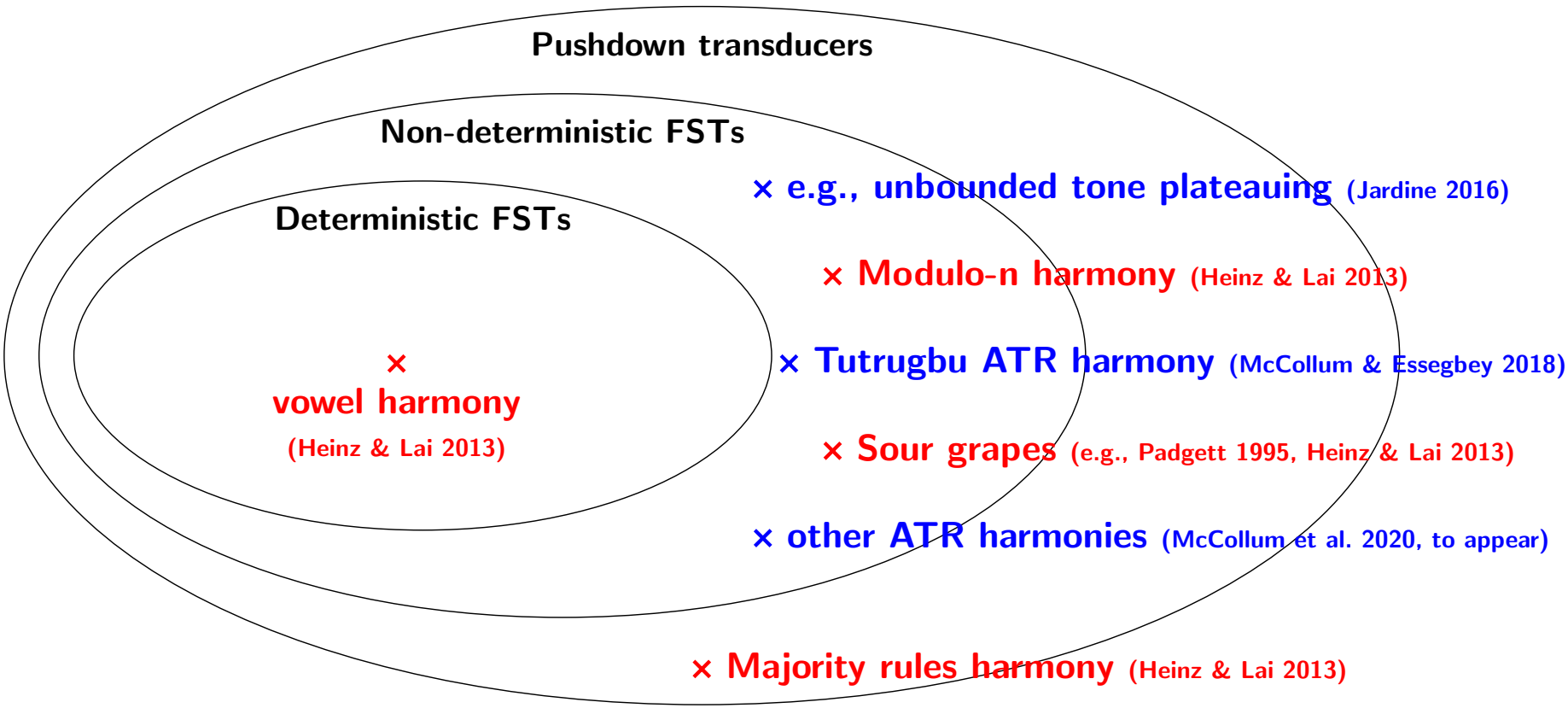
What information is relevant to an undergoer?



What information is relevant to an undergoer?



Is determinism sufficient for phonology?



Research questions

- What information do learners attend to in order to determine the surface realization of an undergoer?
  - in vowel harmony?
  - in tone spreading? *not discussing these results in this talk because we used a slightly different procedure, but ask during the Q&A!*

Overview of experimental conditions

	Myopic	**Non-myopic**
Vowel harmony	blocker offset 0 from trigger	blocker offset 1 from trigger
Tone	blocker offset 0 from trigger	blocker offset 1 from trigger
At test:	extend to offset 1?	extend to offset 2?

Outline

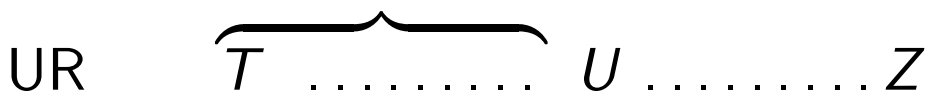
1 Background

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What information is relevant to an undergoer?



Only upstream information?

(1) Language A

a. $/ - - - / \quad \rightarrow \quad [- - -]$

b. $/ + - - / \quad \rightarrow \quad [+ + +]$

Only upstream information?

What if we had an opaque vowel □?

(2) Language A, cont.

a. $/ + \square - / \quad \rightarrow \quad [+\square-]$

b. $/ + - \square / \quad \rightarrow \quad [+ + \square]$

No lookahead: the realization of $/ - /$ is only dependent on upstream information. Maps that exhibit no lookahead are myopic.

What if upstream information alone isn't enough?

(3) Language B

a. $/ + - - / \quad \rightarrow \quad [+ + +]$

b. $/ + \square - / \quad \rightarrow \quad [+\square -]$

c. $/ + -\square / \quad \rightarrow \quad [+ - \square]$

Lookahead: the realization of $/ - /$ is dependent on downstream information in addition to upstream information. Maps that exhibit lookahead are non-myopic.

Does it matter how far downstream Z is?

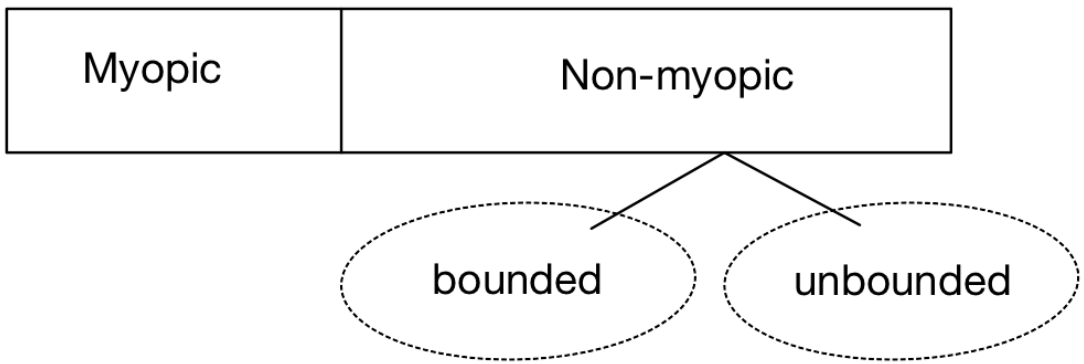
	UR	**Language** B'	**Language** B''
a.	$/+-\square/$	$[+-\square]$	$[+-\square]$
b.	$/+--\square/$	$[+--\square]$	$[+--\square]$
c.	$/+---\square/$	$[+---\square]$	$[+---\square]$
d.	$/+----\square/$	$[+----\square]$	$[+----\square]$
e.	$/+-----\square/$	$[++---\square]$	$[+-----\square]$
f.	$/+------\square/$	$[+++---\square]$	$[+------\square]$
g.	$/+-------\square/$	$[++++----\square]$	$[+-------\square]$
	...	...	...
n.	$/+-^{n}\square/$	$[+\,+^{n-4}\,-^{4}\square]$	$[+\,-^{n}\,\square]$
		bounded non-myopia	unbounded non-myopia
		bounded lookahead	unbounded lookahead

Interim summary

Ability to consider downstream information:

How far away the downstream information is:

A FST generating this mapping requires:

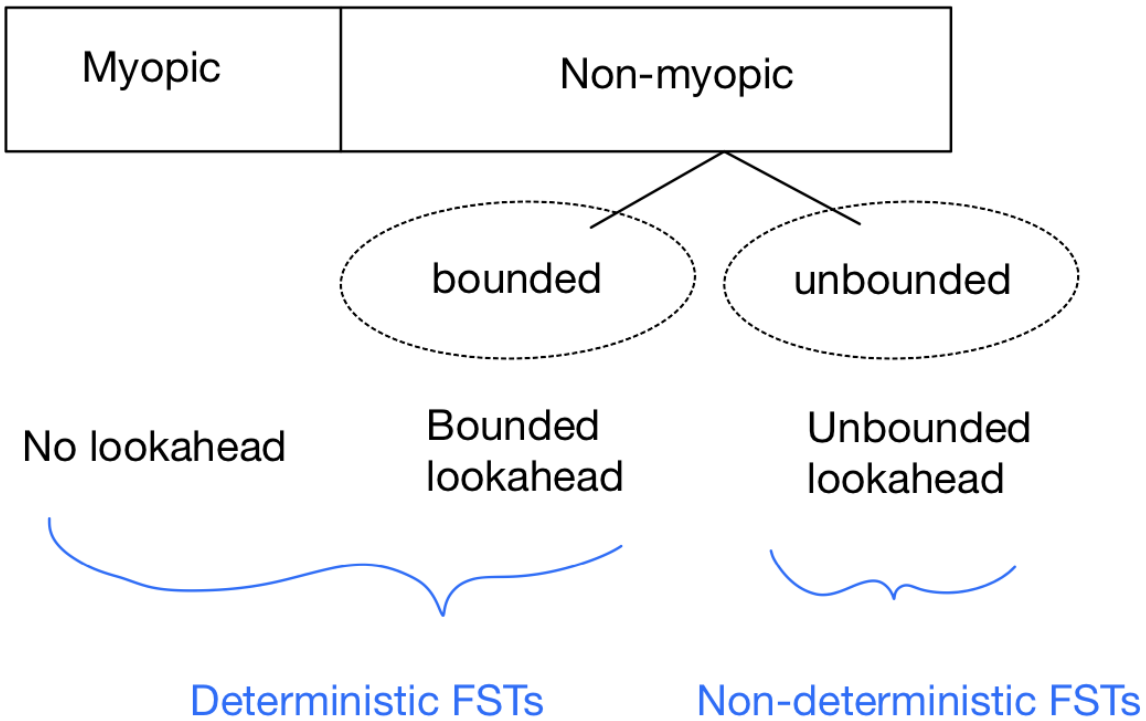


Interim summary

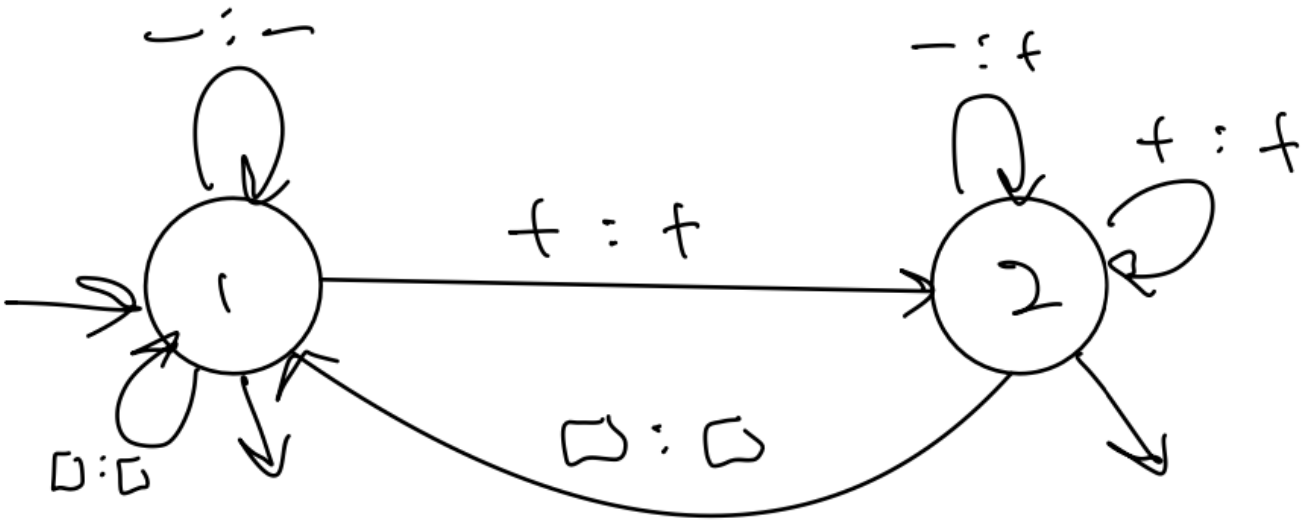
Ability to consider downstream information:

How far away the downstream information is:

A FST generating this mapping requires:



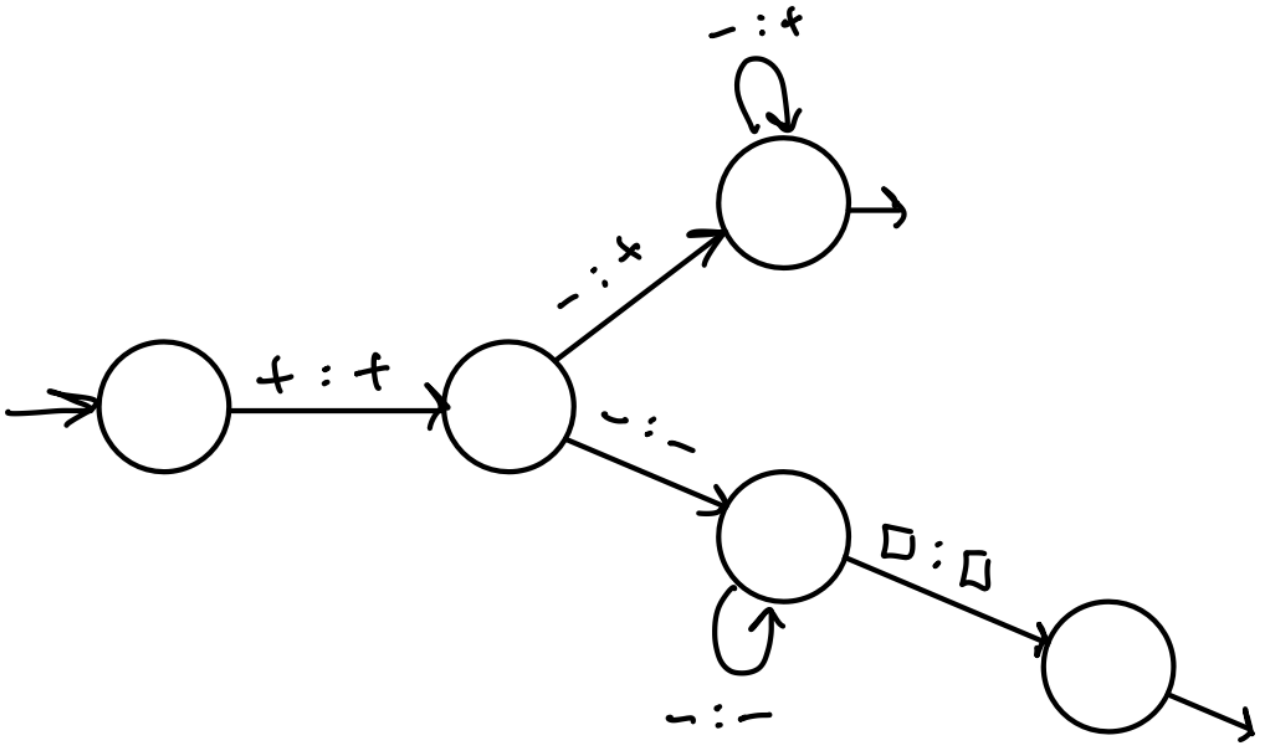
Deterministic FSTs



$$/+--/ \quad \rightarrow \quad [+++]$$
$$/+-\square/ \quad \rightarrow \quad [++\square]$$

- there is exactly one initial state
- there is no state that has two outgoing transitions that share the same input symbol

Non-deterministic FSTs

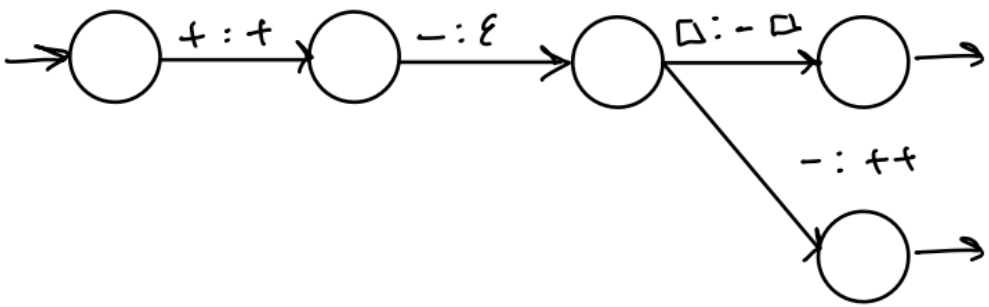


$$/ + -^{n}\square / \quad \rightarrow \quad [+ -^{n} \square]$$

- more than one possible path through the machine for a given input string is allowed

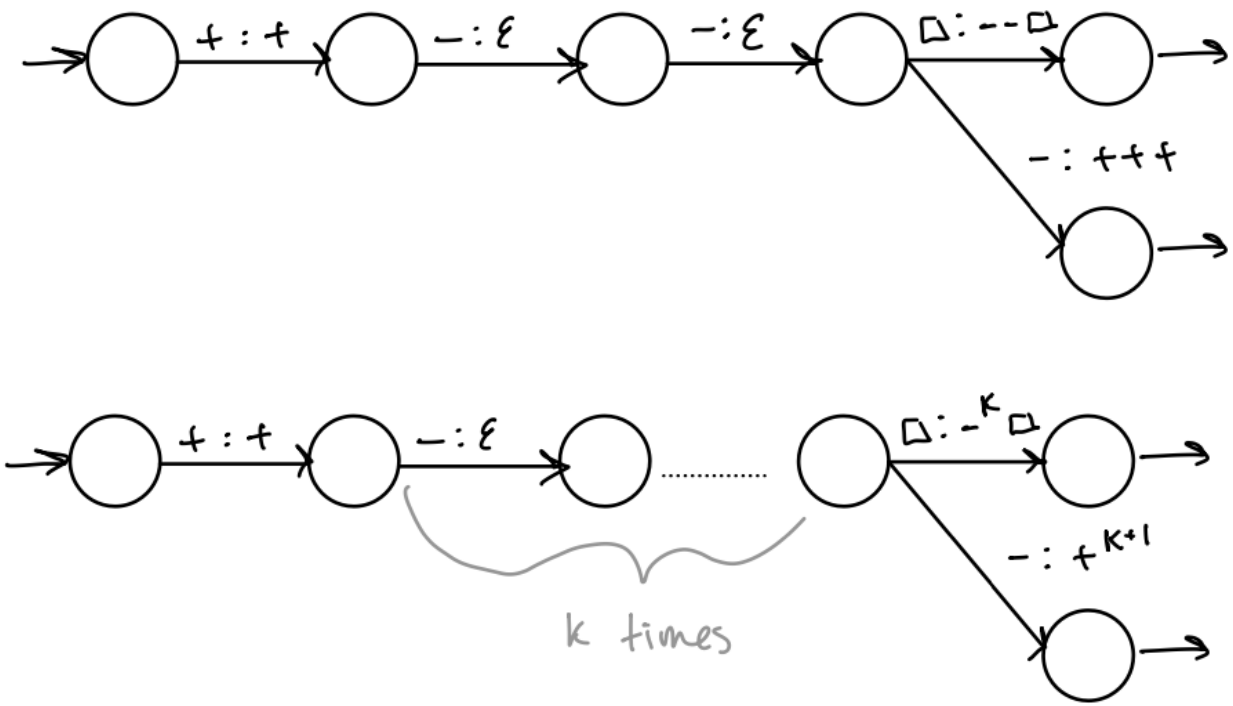
But what about bounded non-myopia?

How do we handle $/ + -\square/ \quad \rightarrow \quad [+ - \square]$?



- deterministic FSTs have a limited ability to "wait" to determine an output symbol

But what about bounded non-myopia?



- when this trick won't work: if for any fixed length-k distance, there is always some input string where the downstream information is length-$k+1$ from the undergoer

Outline

1 Background

2 Methods

3 Results

4 Discussion

Methods

- Artificial grammar learning paradigm (AGL)
- Myopic blocking previously demonstrated with AGL in Finley (2015)
- Administered remotely via Labvanced (Finger et al. 2017)

Design

- Participants asked to form diminutive, feminine, plural, and combinations of two of those suffixes (diminutive plural, feminine diminutive, feminine diminutive plural) of known and unknown objects in an artificial language

AGL instructions

This is feminine.



This is diminutive feminine.



When you are ready to start, click the button below.

Next

AGL training phase

- Training consisted of 3 blocks of 144 words, separated by 10-question attention checks
- Each trial: 2 audio stimuli of stems and suffix(es) + images of the meanings, trial order was randomized
- Training lasted about 25 minutes ($3 \times \sim 8$ minutes)
- Participants could not advance to the next trial via 'space' key until the audio stimulus finished playing

AGL training phase





null / 144

Experimental conditions

	Myopic	**Non-myopic**
Segmental	blocker offset 0 from trigger $/+-\ -/\rightarrow[+++]$ $/+\square-/\rightarrow[+\square-]$ e.g., dotumop, dotætep	blocker offset 1 from trigger $/+-\ -/\rightarrow[+++]$ $/+-\square/\rightarrow[+-\square]$ e.g., dotumop, dotepæt
At test:	extend to offset 1? $/+-\square-/$ $[++\square-]$ vs. $[+-\square-]$ e.g., mobumætep vs. mobimætep	extend to offset 2? $/+-\ -\square/$ $[++-\square]$ vs. $[+-\ -\square]$ e.g., mobumopæt vs. mobimepæt

Stimuli

- 24 monosyllabic CVC stems and 3 distinct suffixes; 144 training items in total
- Stems were based on training items from Finley (2015)
  - consonant inventory [p, t, k, b, d, g, m, n]
  - vowel inventory [i, e, u, o, æ]
- All words were stress-initial

Stimuli

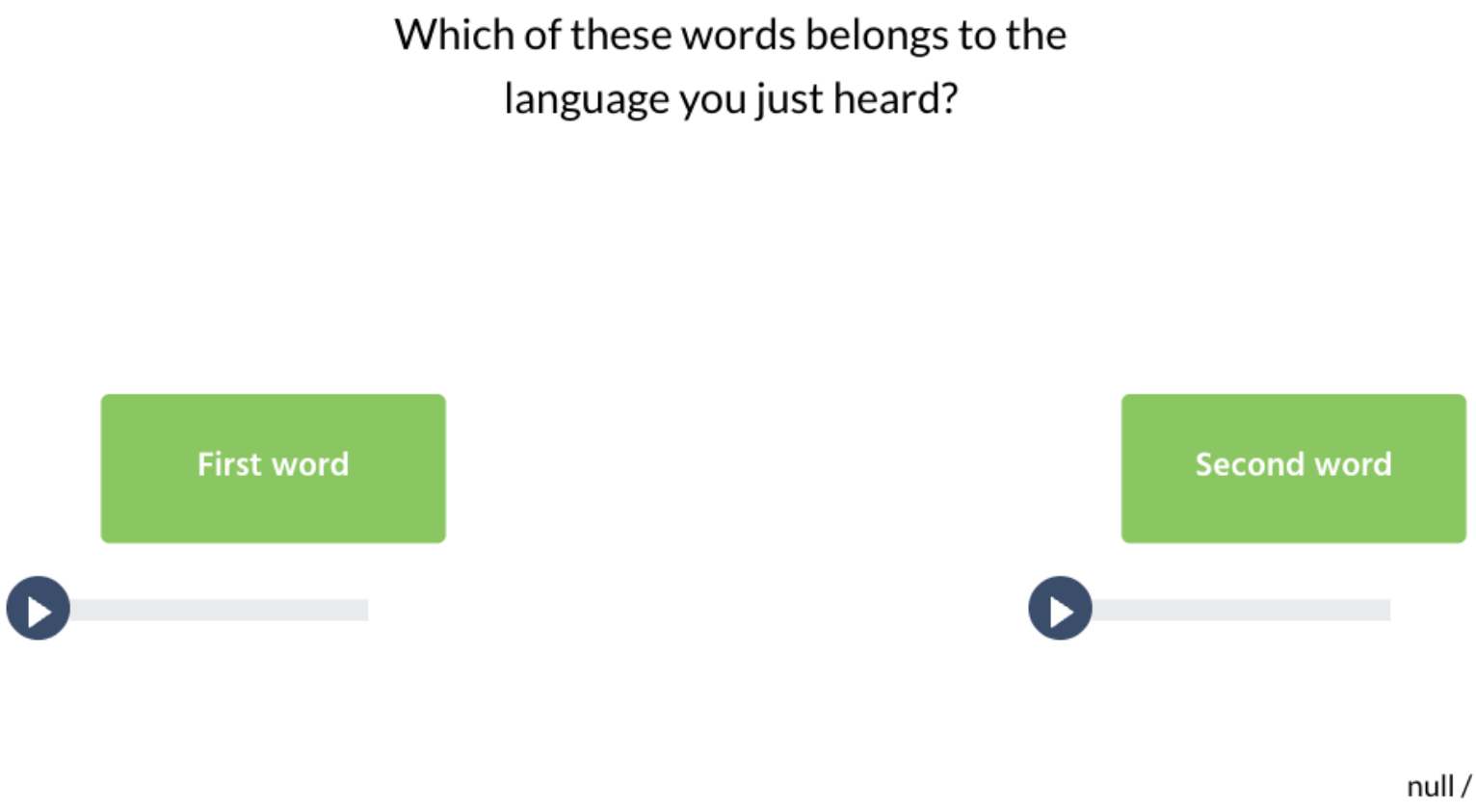
Summary of stimuli

Training:	**Both myopic and non-myopic conditions**					**Myopic only**	**Non-myopic only**
	Stem	Dim	Pl	Fem	Dim fem	Dim pl	Dim pl
Vowel harmony	dim dot	dimep dotop	dimæt dotæt	dimim dotum	dimimep dotumop	dimætep dotætep	dimepæt dotepæt
At test:	**Both conditions**			**Myopic only**		**Non-myopic only**	
Spreading learned?	kebimep – kebimop mobumop – mobumep						
Blocker learned?				kebætep – kebætop mobætop – mobætep		kebepæt – kebopæt mobopæt – mobepæt	
Extra lookahead?				kebimætep – kebumætep mobumætep – mobimætep		kebimepæt – kebumepæt mobumepæt – mobimepæt	

AGL test phase

- Presented two alternative surface realizations in rapid succession (50 trials)
- Asked to pick the word belonging to the language they just heard

AGL test phase



Participants

- 76 adults (targeted 20 per condition): 18 years or older; normal speech, hearing, vision
- 31 participants were excluded for failing a perceptual AXB task
  - tested participants' ability to discriminate vowel rounding in the same height (Finley 2015)
  - Participants scoring under 75% were excluded
- Final sample: 45 adults (23 myopic vowel harmony, 22 non-myopic vowel harmony)

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Results

- For each test trial, participant harmonic responses were recorded
- Mixed effects logistic regression models in R were used to model the log odds of choosing the harmonic response

Results

Because assessing the learning of blocking necessitates the learning of feature spreading, we will break up the presentation of the results into the following questions:

(4) a. Was feature spreading (diminutive feminine) learned?

b. Was the blocker (diminutive plural) learned?

c. Did participants extend to additional blocker offset (diminutive feminine plural)?

Was feature spreading learned?

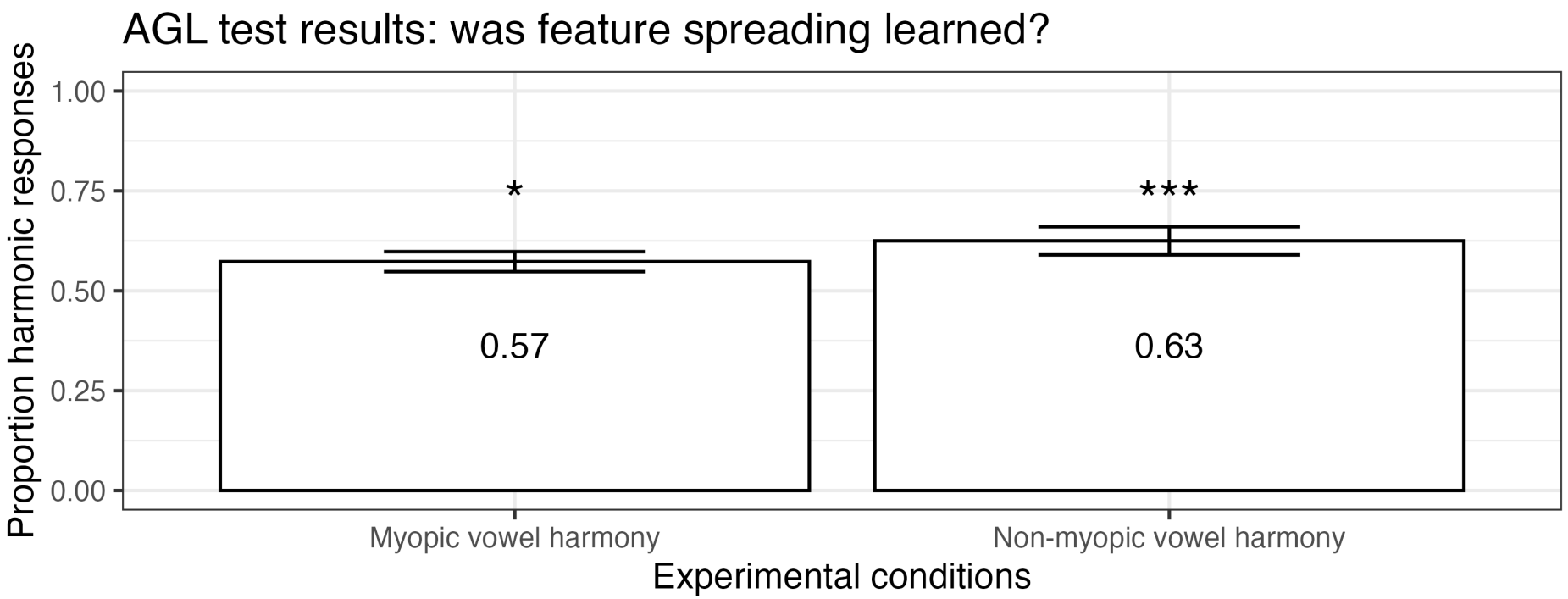
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	Stem	Dim	Pl	Fem	Dim fem	Dim pl	Dim pl
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At test:	**Both conditions**	**Myopic only**	**Non-myopic only**
Spreading learned?	kebimep – kebimop mobumop – mobumep		
Blocker learned?		kebætep – kebætop mobætop – mobætep	kebepæt – kebopæt mobopæt – mobepæt
Extra lookahead?		kebimætep – kebumætep mobumætep – mobimætep	kebimepæt – kebumepæt mobumepæt – mobimepæt

Was feature spreading learned?

Do participants prefer, e.g., *mobumop* or *mobumep*? What about *kebimep* or *kebimop*?



If feature spreading was learned, participants should have selected the harmonic response more often than chance.

Was feature spreading learned?

Experimental condition	Feature spreading learned?	Blocker learned?	Extended to additional offset?
Myopic vowel harmony	✓		
Non-myopic vowel harmony	✓		

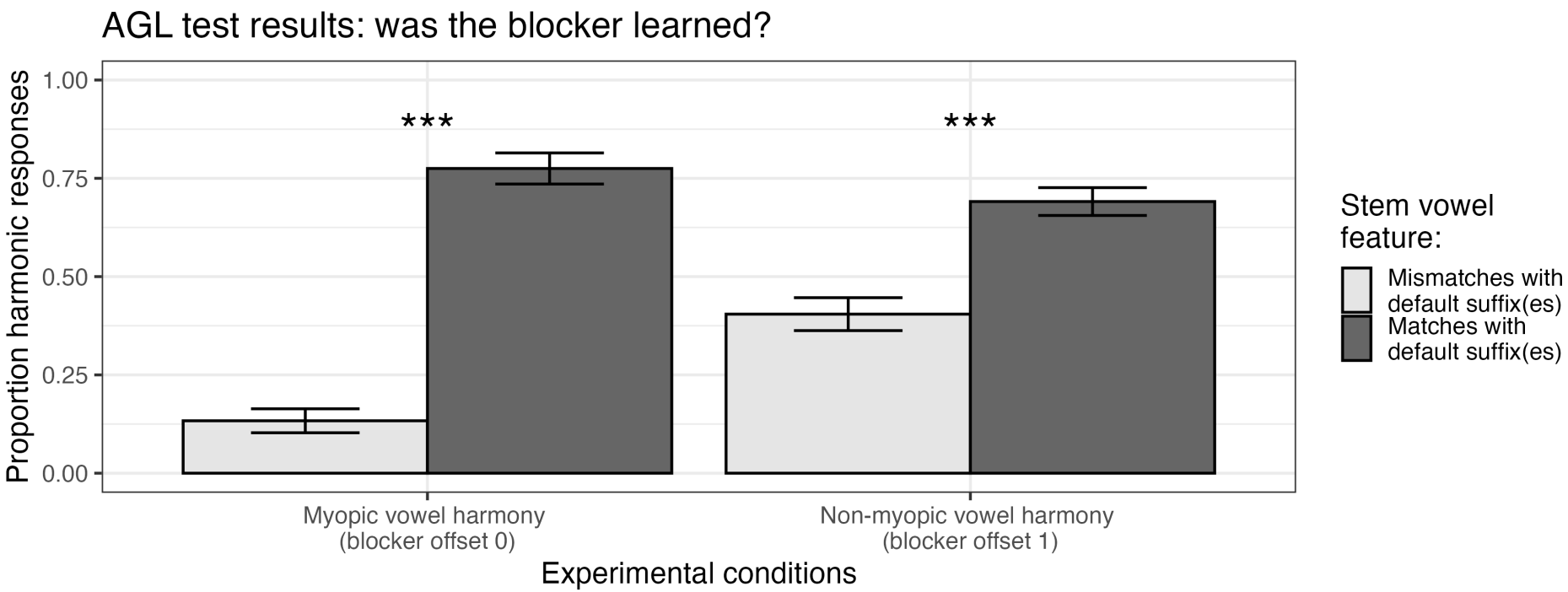
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Extra lookahead?				kebimætep – kebumætep mobumætep – mobimætep		kebimepæt – kebumepæt mobumepæt – mobimepæt	

Was the blocker learned?

Do participants prefer, e.g., *mobætep* or *mobætop*? *mobepæt* or *mobopæt*? What about *kebætep* or *kebætop*? *kebepæt* or *kebopæt*?



If the blocker was learned, participants should have selected the harmonic response more often in cases of passive harmony (stem/default suffix featural match) than in cases of active harmony (stem/default suffix featural mismatch).

Was the blocker learned?

Experimental condition	Feature spreading learned?	Blocker learned?	Extended to additional offset?
Myopic vowel harmony	✓	✓	
Non-myopic vowel harmony	✓	✓	

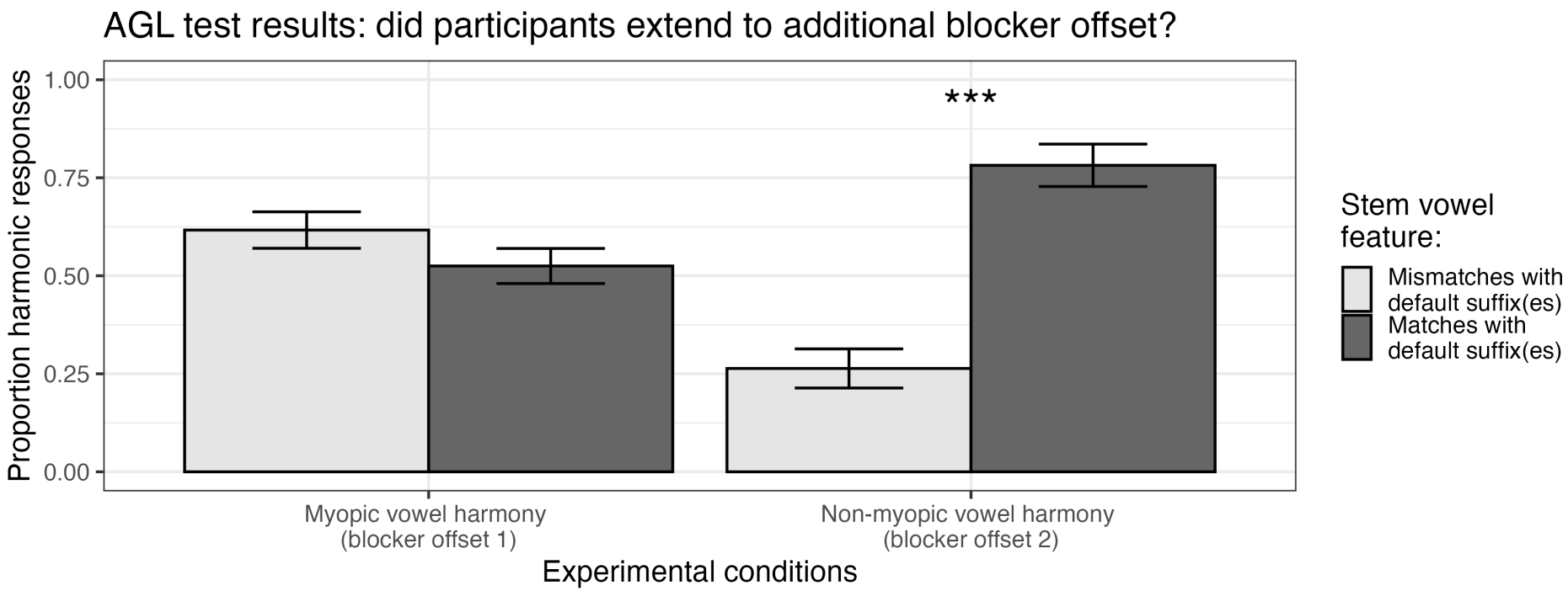
Did participants extend to additional blocker offset?

Summary of stimuli

Training:	**Both myopic and non-myopic conditions**					**Myopic only**	**Non-myopic only**
	Stem	Dim	Pl	Fem	Dim fem	Dim pl	Dim pl
Vowel harmony	dim dot	dimep dotop	dimæt dotæt	dimim dotum	dimimep dotumop	dimætep dotætep	dimepæt dotepæt
At test:	**Both conditions**			**Myopic only**		**Non-myopic only**	
Spreading learned?	kebimep – kebimop mobumop – mobumep						
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Extra lookahead?				kebimætep – kebumætep mobumætep – mobimætep		kebimepæt – kebumepæt mobumepæt – mobimepæt	

Did participants extend to additional blocker offset?

Do participants prefer, e.g., *mobimætep* or *mobumætep*? *mobimepæt* or *mobumopæt*? What about *kebimætep* or *kebumætep*? *kebimepæt* or *kebumopæt*?



If the blocking effect was extended over additional offset, participants should have selected the harmonic response more often in cases of passive harmony (stem/default suffix featural match) than in cases of active harmony (stem/default suffix featural mismatch).

Results summary

Experimental condition	Feature spreading learned?	Blocker learned?	Extended to additional offset?
Myopic vowel harmony	✓	✓	✗
Non-myopic vowel harmony	✓	✓	✓

Research questions

- What information do learners attend to in order to determine the surface realization of an undergoer:
  - in vowel harmony?
    - upstream information ✓
    - downstream information ✓
    - downstream information at an additional distance ✓(only if trained on downstream information)

Outline

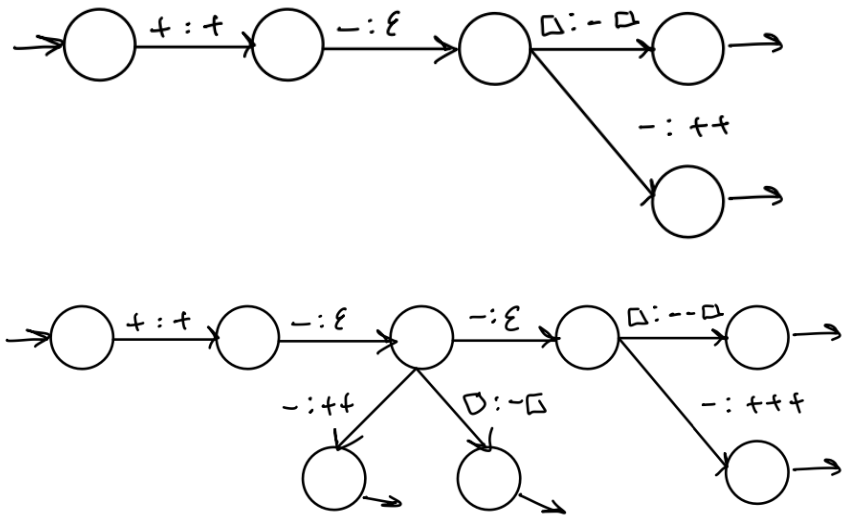
1 Background

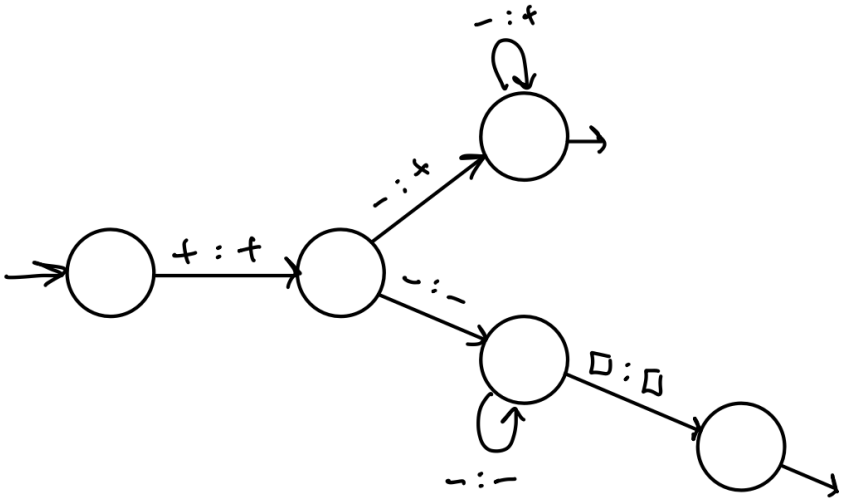
2 Methods

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4 Discussion

Are these results evidence of non-determinism?





- Participants learned a bound on the lookahead that's greater than what they observed in training
- It's possible they learned a bounded lookahead, but if they did, it's a bound that's greater than 1
- More appealing hypothesis: unbounded lookahead

Takeaways

- Non-myopic processes are learned in vowel harmony
- Participants who were trained on a non-myopic process learned a lookahead with a greater bound than they observed in training
  - Participants preferred lookahead 2 over lookahead 1 in longer test items, despite only having evidence in training for lookahead 1
  - If determinism is sufficient for phonology, this is unexpected!
- Participants trained on strictly myopic input did not reach non-myopic generalizations
- (Not discussed in this talk) similar results in tone, ask me during the Q&A

References I

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