DISTINGUISHING BREATHY CONSONANTS AND VOWELS IN GUJARATI

christina m. esposito, macalester college
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icphs-19, melbourne, 9 august 2019

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Big question

- Several lgs have contrastive **breathiness** on:
  - **Consonants** (C$^{\text{ɦ}}$)

Bengali (Khan 2010)
[gaʃ] 'you sing'
[g$^{\text{ɦ}}$aʃ] 'grass'

	V	V vs. V̤
C	English Punjabi Std. Khmer	
C vs. C$^{\text{ɦ}}$	**Bengali** Javanese Tsonga	

Big question

- Several lgs have contrastive **breathiness** on:
  - **Consonants** (C$^{\text{ɦ}}$), or
  - **Vowels** (V̤)

W. Khmer (Wayland & Jongman 2003)
[pɔːk] 'by chance'
[pɔ̤ːk] 'bumped'

	V	V vs. V̤
C	English Punjabi Std. Khmer	Zapotec lgs. Mazatec lgs. **W. Khmer**
C vs. C$^{\text{ɦ}}$	Bengali Javanese Tsonga	

Big question

- But very **few have both**: why?
- Is it that $C^{ɦ}$ has to express its breathiness on adjacent V, generating confusion with $C\ddot{V}$?

Gujarati (Esposito & Khan 2012)

[$b^{ɦ}ar$] 'burden' [$b\ddot{a}r$] 'outside'

	V	V vs. $\ddot{V}$
C	English Punjabi Std. Khmer	Zapotec lgs. Mazatec lgs. W. Khmer
C vs. $C^{ɦ}$	Bengali Javanese Tsonga	**Gujarati** White Hmong Wa

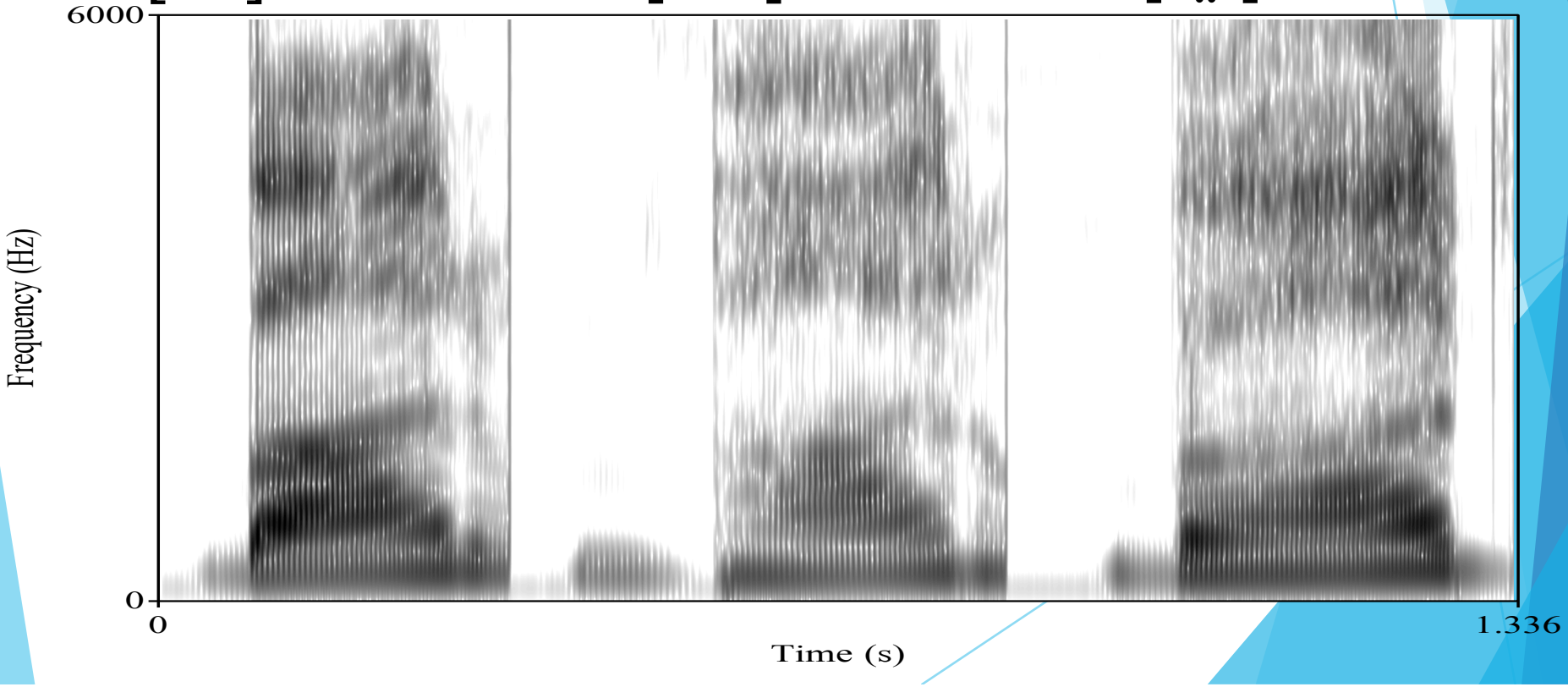
Gujarati breathiness

- Well-known minimal triplet of Gujarati:

All modal [baɾ] **'twelve'**

Breathy $C^{ɦ}$ [$b^{ɦ}aɾ$] **'burden'**

Breathy $V̤$ [bạ̤ɾ] **'outside'**



Narrow question

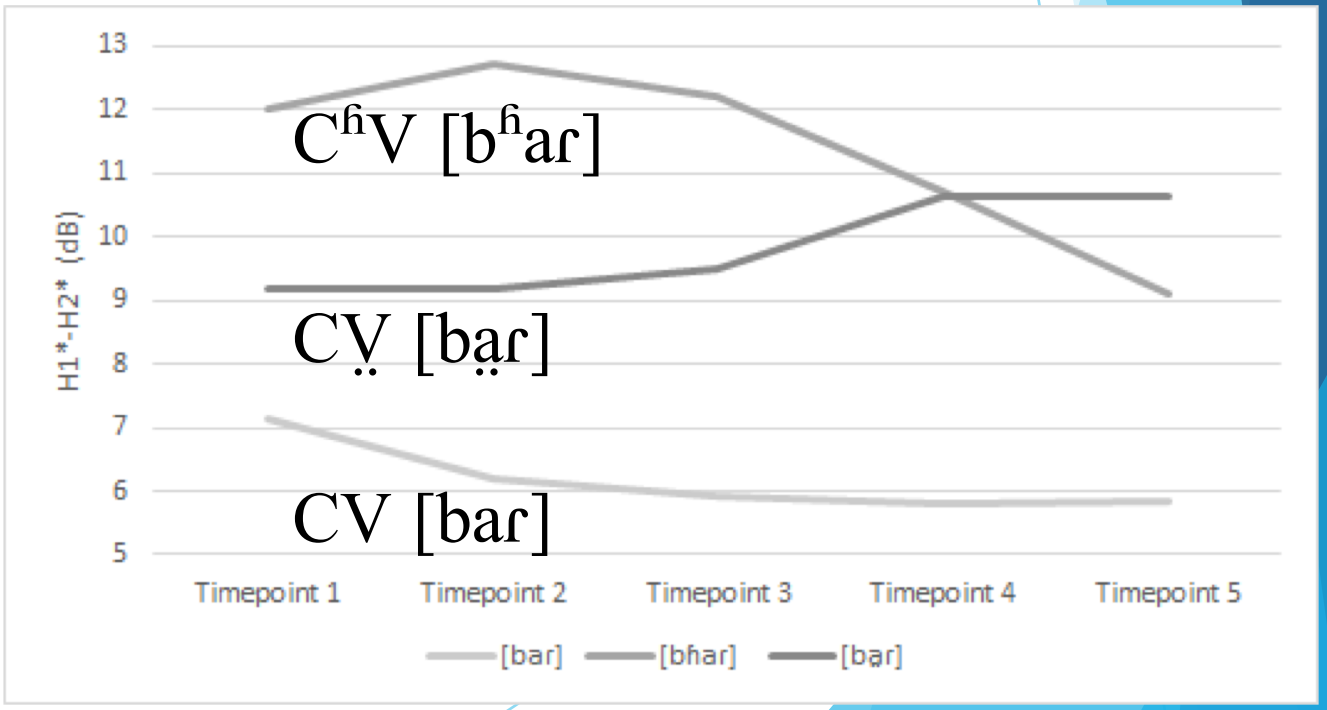
- In their **production**, Gujarati speakers distinguish $C^{ɦ}V$ vs. $C\ddot{V}$ vs. CV (Esposito & Khan 2012)
  - True even for heritage speakers (Nara 2017)
- They are also **highly sensitive** to tiny variations in H1–H2 in perception (Kreiman, Gerratt, & Khan 2010)
  - True even for heritage speakers
  - But not tested for 3-way comparison
- So can speakers use this sensitivity to distinguish $C^{ɦ}V$ vs. $C\ddot{V}$ vs. CV in **perception**?

Predictions

- C$^{\text{ɦ}}$V & C◌̤ use the **same cues** of breathiness (Khan 2012; Dave 1967; Fischer-Jørgensen 1967)
  - **Steeper spectral slope**, measured as higher H1-H2, H1-A1, H1-A2, H1-A3, H2-H4
  - **Noisier**, measured as lower CPP, HNR
- Suggests **C$^{\text{ɦ}}$V and C◌̤ are confusable**

Predictions

- But C$^{\text{ɦ}}$V & C̤V differ in cue realization (Esposito & Khan 2012)
  - C$^{\text{ɦ}}$V has a **shorter, more extreme** breathiness
  - C̤V has **longer, more subtle** breathiness
- Suggests **C$^{\text{ɦ}}$V and C̤V can be distinguished**



Predictions

- Cʱ and V̤ are not equally "stable" (Cardona & Suthar 2003; Mistry 1997; Modi 1987; Nair 1979; Dave 1967; Pandit 1957)
- V̤ may be **especially susceptible to merger** w/ V

	Breathy Cʱ	**Breathy V̤**
Regionally	Stable	V̤ → V in some varieties
Orthographically	Dedicated graphemes	Represented with ह <ɦ> or not at all
In careful speech	Stable	V̤ → VɦV
In fast speech	CʱV → CV̤ VCʱ → V̤C	V̤ → V

Overview of methods

- 3 perception tasks
  - Free-sort
  - AX discrimination
  - Picture-matching

More open-ended

More lexically-determined

- All tasks used the same minimal triplet stimuli, taken from production study (Khan 2012)
  - Naturally-produced
  - Excised from connected speech
  - Utterance-initial

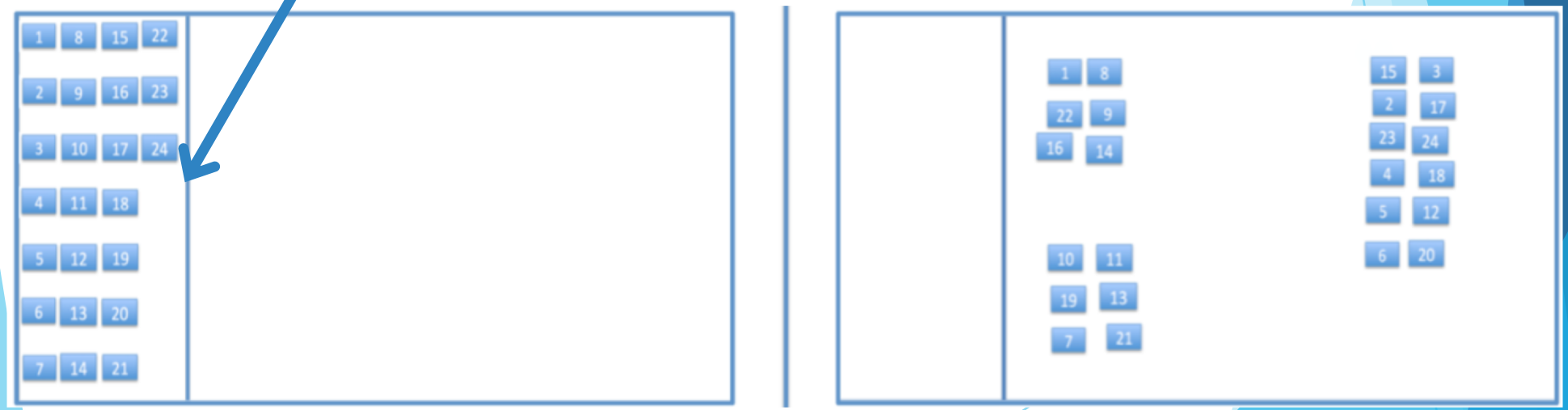
Participants

Talker #	Sex	Age	Home city
T1	F	22	Mumbai, Maharashtra, India
T2	F	20s	Mumbai, Maharashtra, India
T3	F	23	Mumbai, Maharashtra, India
T4	F	30	Mumbai, Maharashtra, India

Listener #	Sex	Age	Birthplace
L1	M	23	Ahmedabad, Gujarat, India
L2	M	30	Vadodara, Gujarat, India
L3	M	23	Mumbai, Maharashtra, India
L4	M	26	Ahmedabad, Gujarat, India
L5	F	52	Bardoli, Gujarat, India
L6 (heritage)	F	19	Fostoria, Ohio, USA

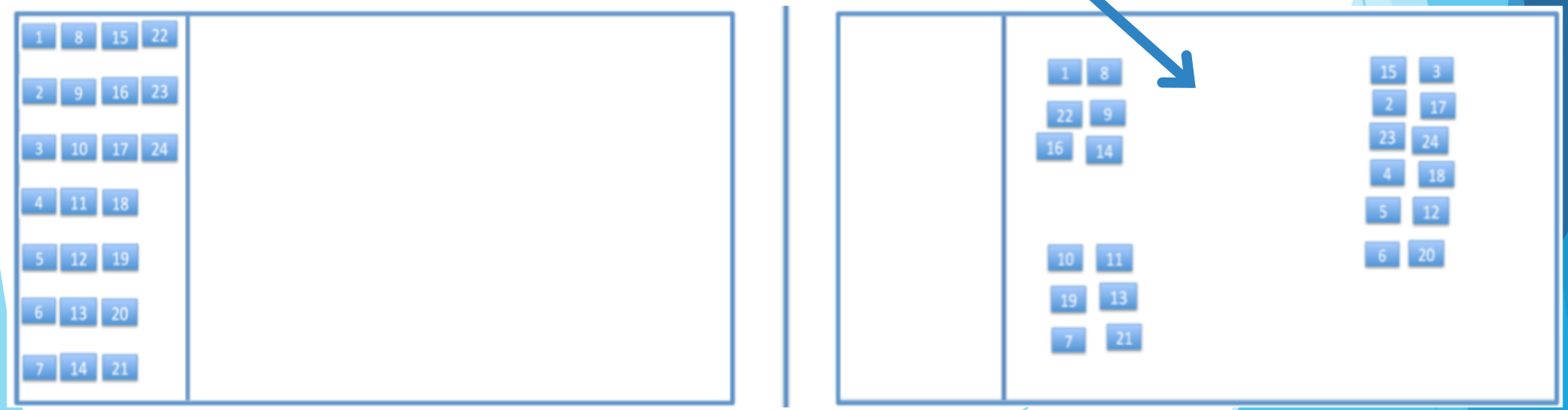
Task 1: free sort

- 24 **audio stimuli presented as visual icons**
  - Could click & listen as many times as desired



Task 1: free sort

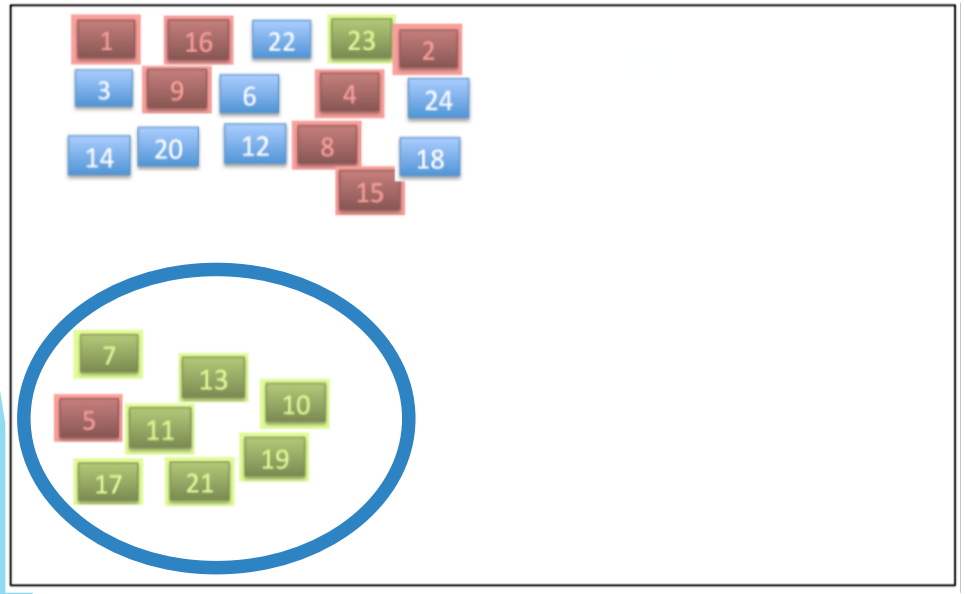
- 24 **audio stimuli presented as visual icons**
  - Could click & listen as many times as desired
- Listeners asked to **drag and sort** into as many groups as desired (2+)
  - Not given any further instruction



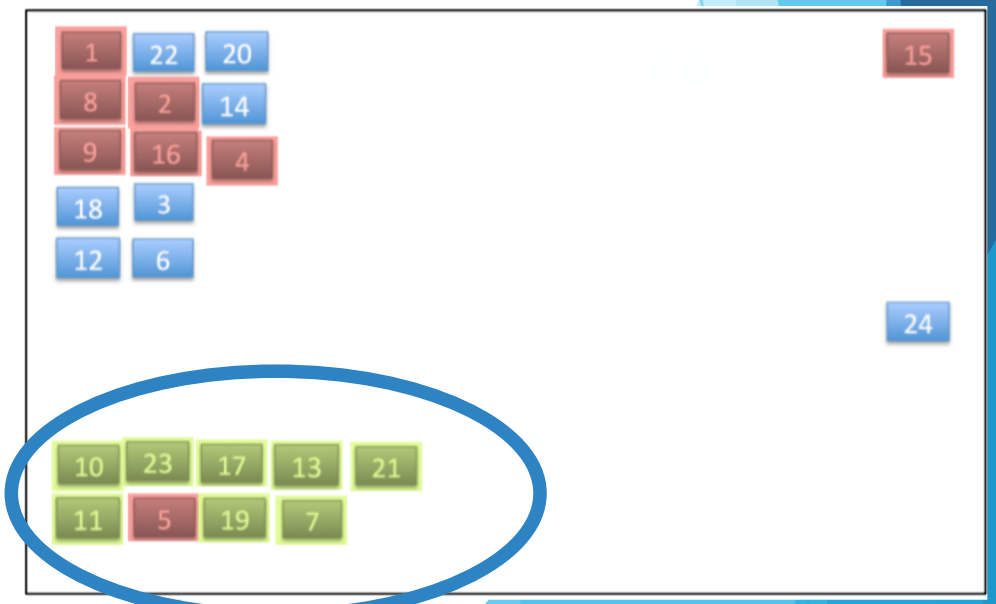
Task 1: free sort

- Listeners 3 & 4 made:
  - a [bʱaɾ] group

Listener 4



Listener 3

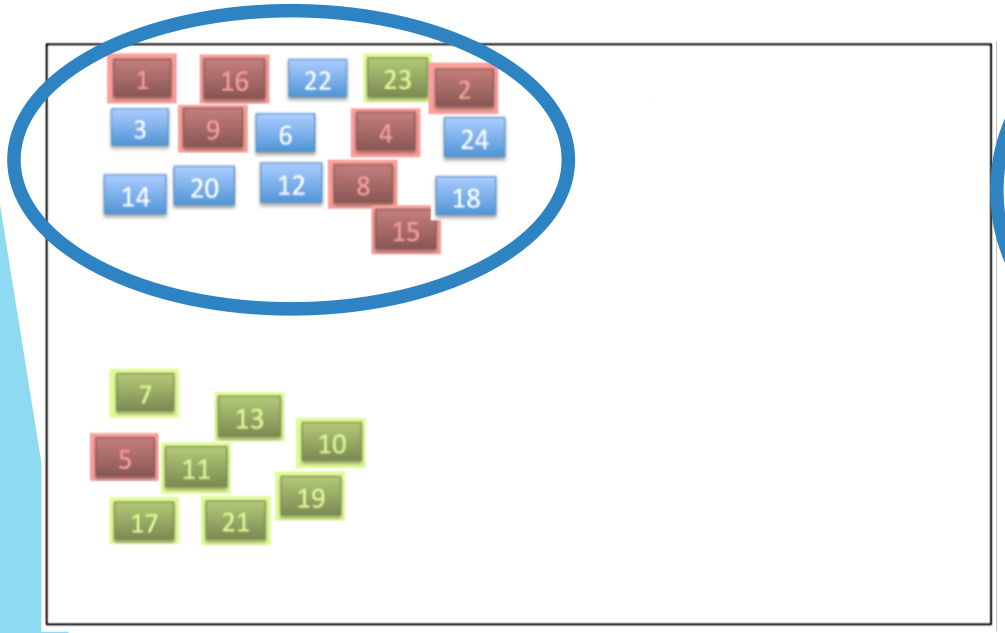


Task 1: free sort

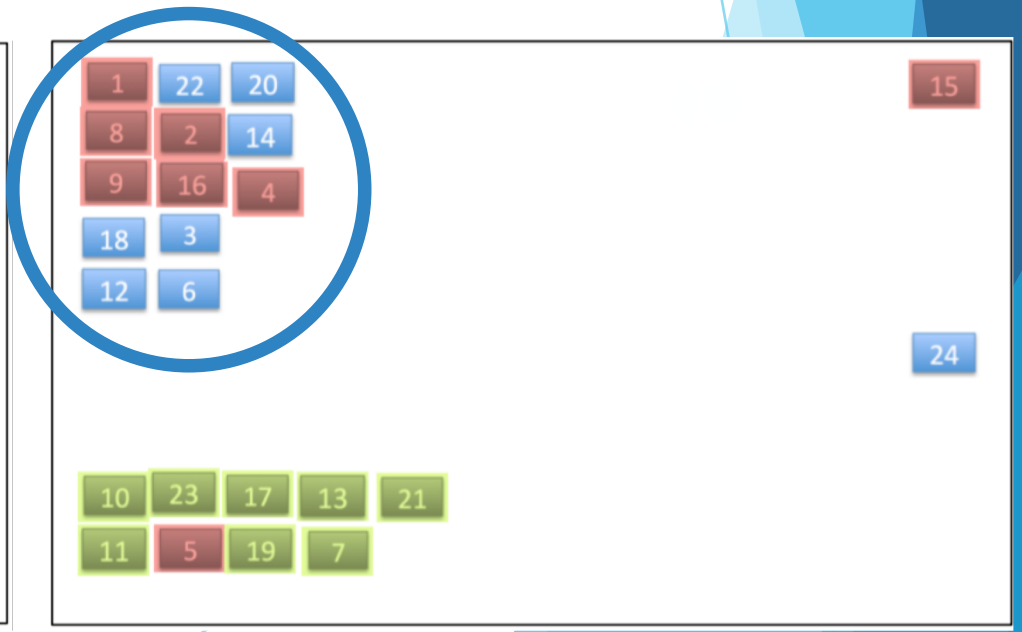
- Listeners 3 & 4 made:
  - a [bʱaɾ] group
  - a [baɾ] + [bạɾ] group
  - suggests perceptual overlap

CV CʱV CV̤

Listener 4



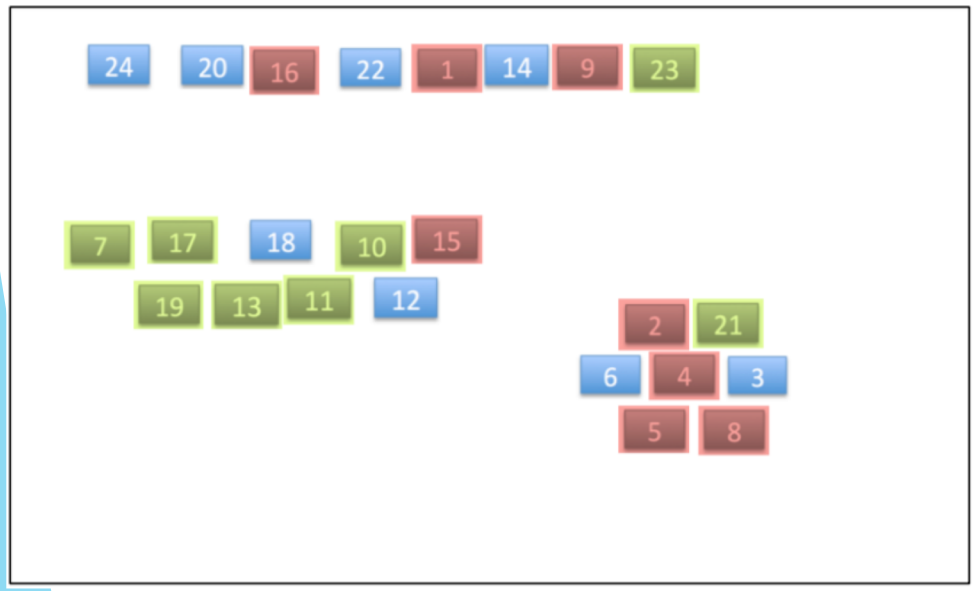
Listener 3



Task 1: free sort

- Listener 5 made three groups
- Roughly the three lexical items, with lots of mixing

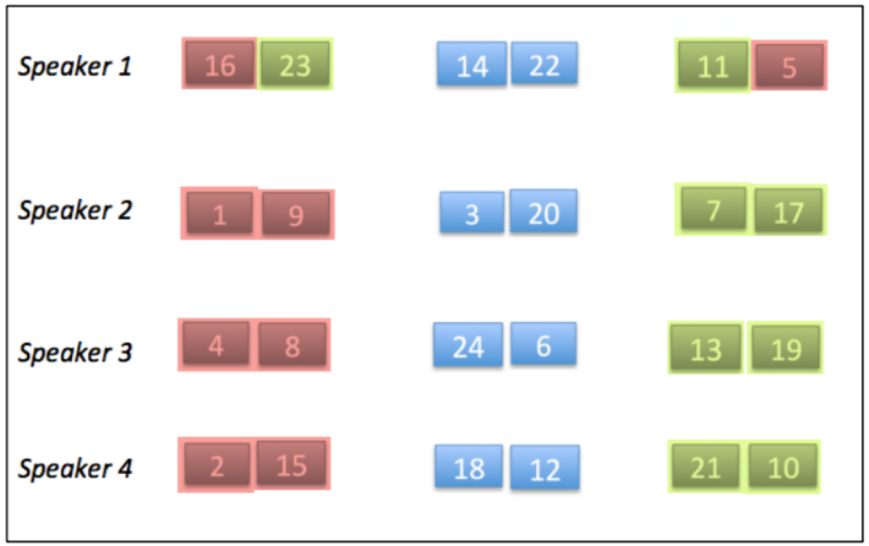
Listener 5



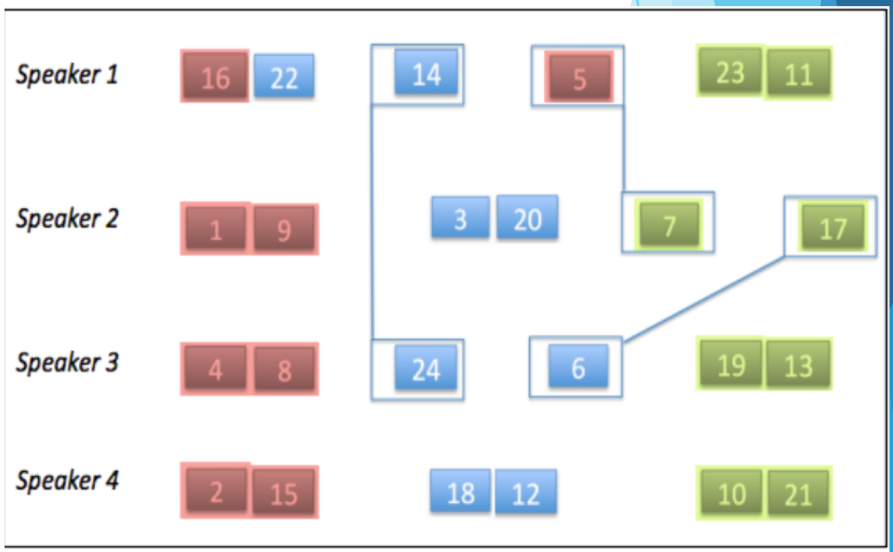
Task 1: free sort

- Listeners 1 & 2 went further
- Grouped by word and talker
- Suggests highly sophisticated auditory skill

Listener 1



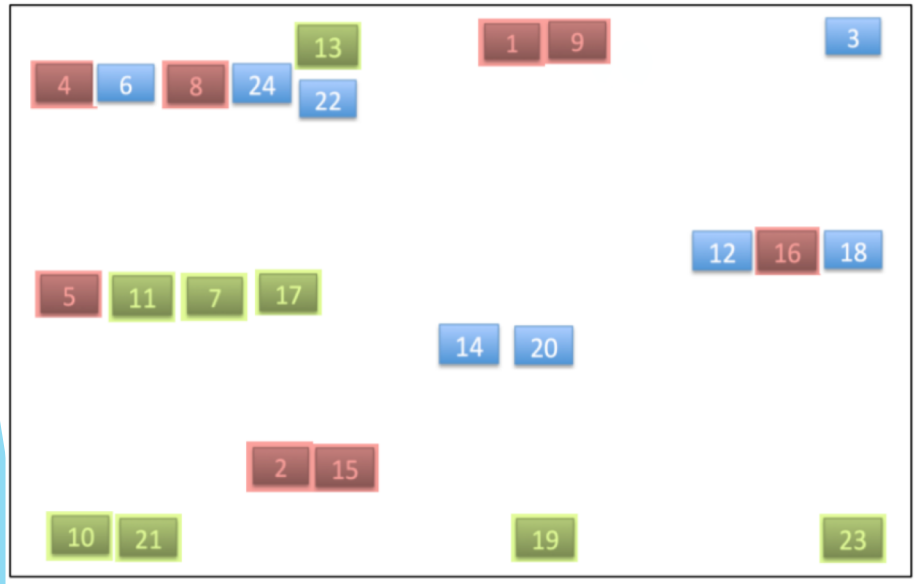
Listener 2



Task 1: free sort

- Listener 6 made groups we could not interpret

Listener 6

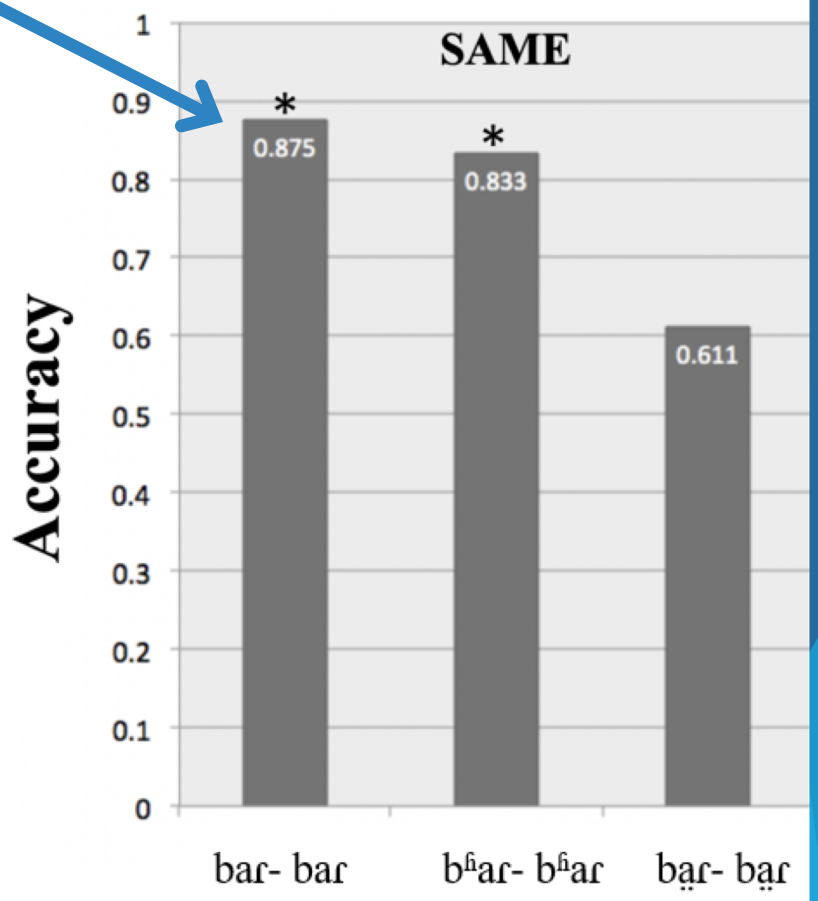


Task 2: AX discrimination

- Classic **AX discrimination** task
  - Listeners heard all 54 pairs of stimuli
  - No pair had the same talker for both words
  - ISI=300ms, response time <1000ms, no rep.
  - Clicked સરખું 'same' or જુદું 'different'
- Results displayed as
  - Bars for % correct
  - Chi-square tests for significance

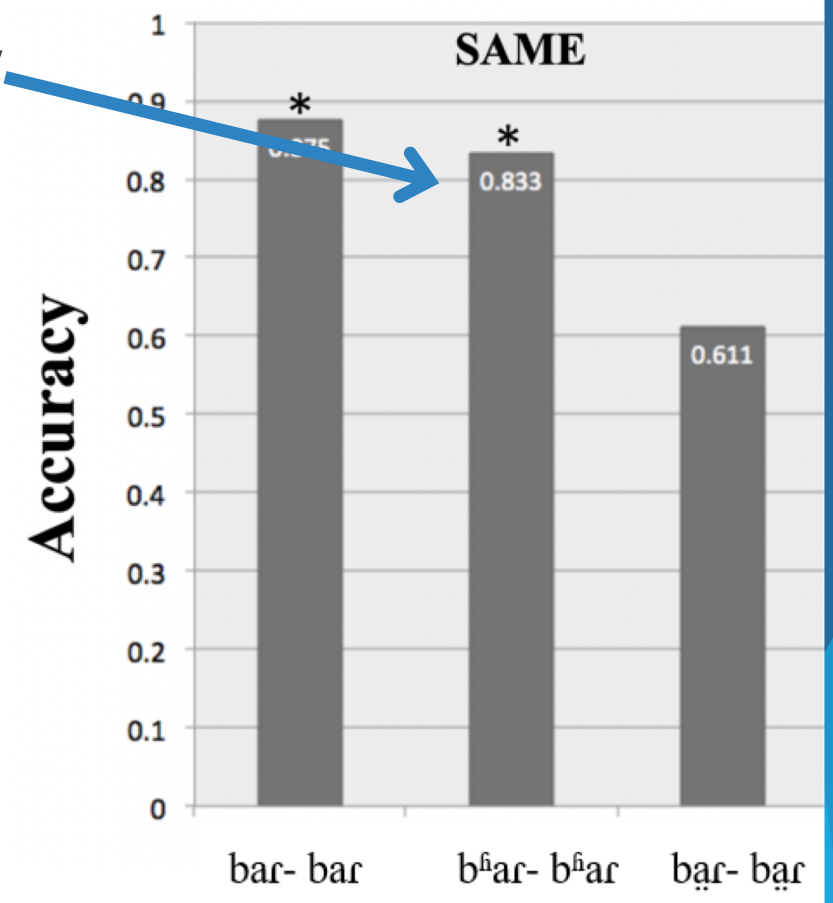
Task 2: AX discrimination

- In “same” trials:
  - [baɾ]-[baɾ] was clearly “same”



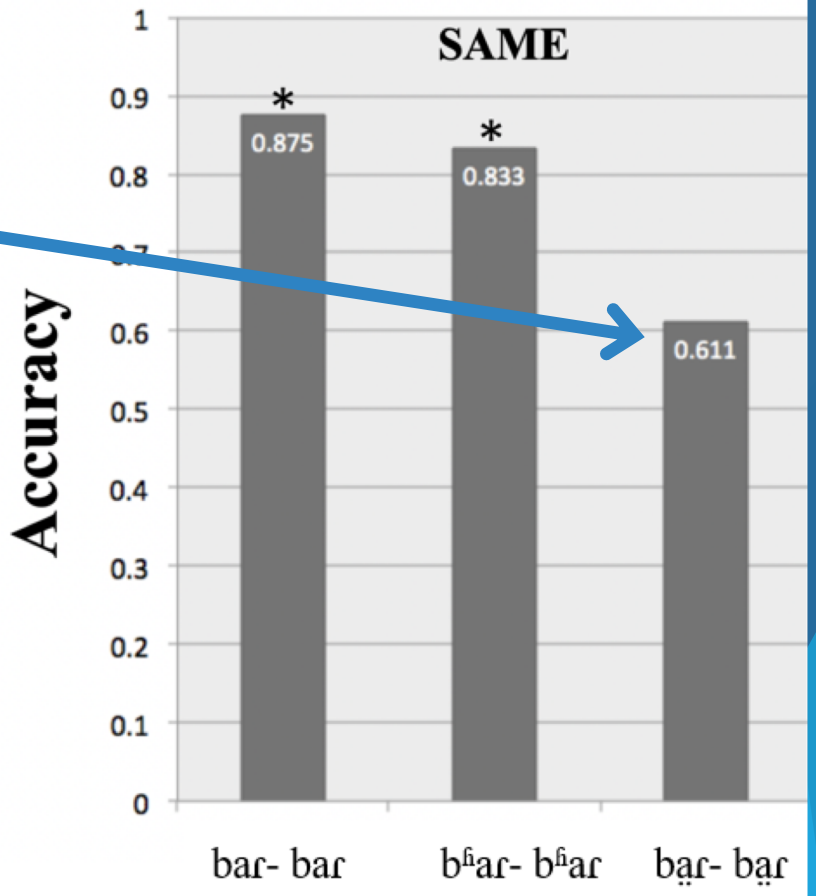
Task 2: AX discrimination

- In "same" trials:
  - [baɾ]-[baɾ] was clearly "same"
  - [bʱaɾ]-[bʱaɾ] was clearly "same"



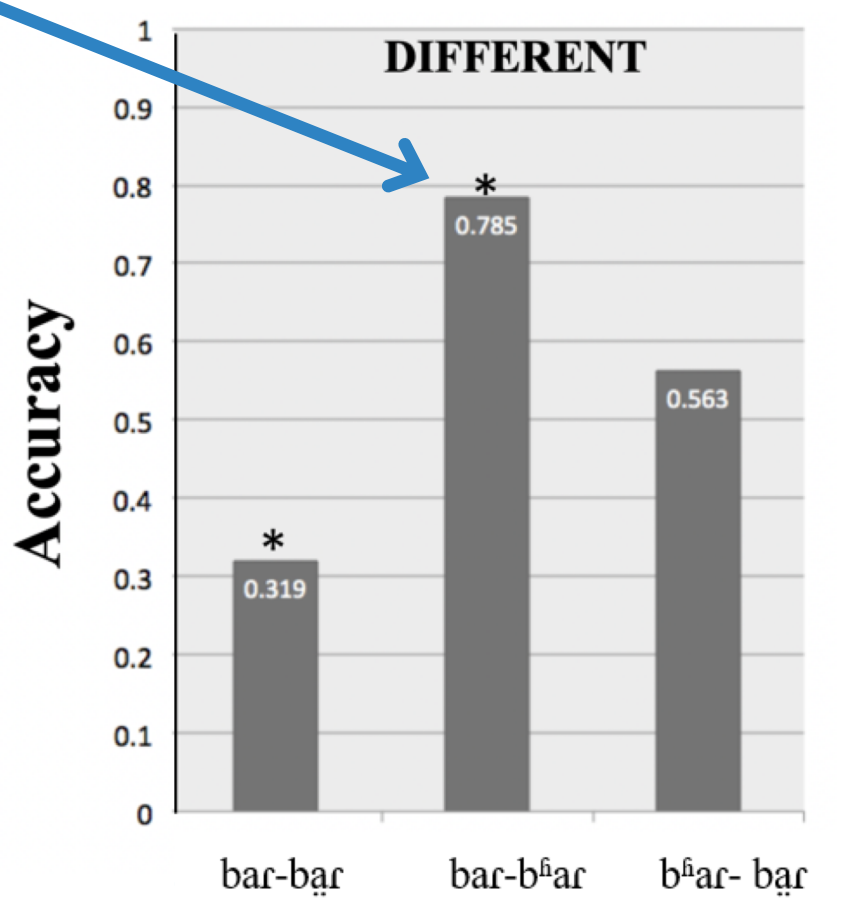
Task 2: AX discrimination

- In "same" trials:
  - [baɾ]-[baɾ] was clearly "same"
  - [bʱaɾ]-[bʱaɾ] was clearly "same"
  - [bạɾ]-[bạɾ] responses were not sig. different from chance
- Suggests [bạɾ] is hard to identify as a single category



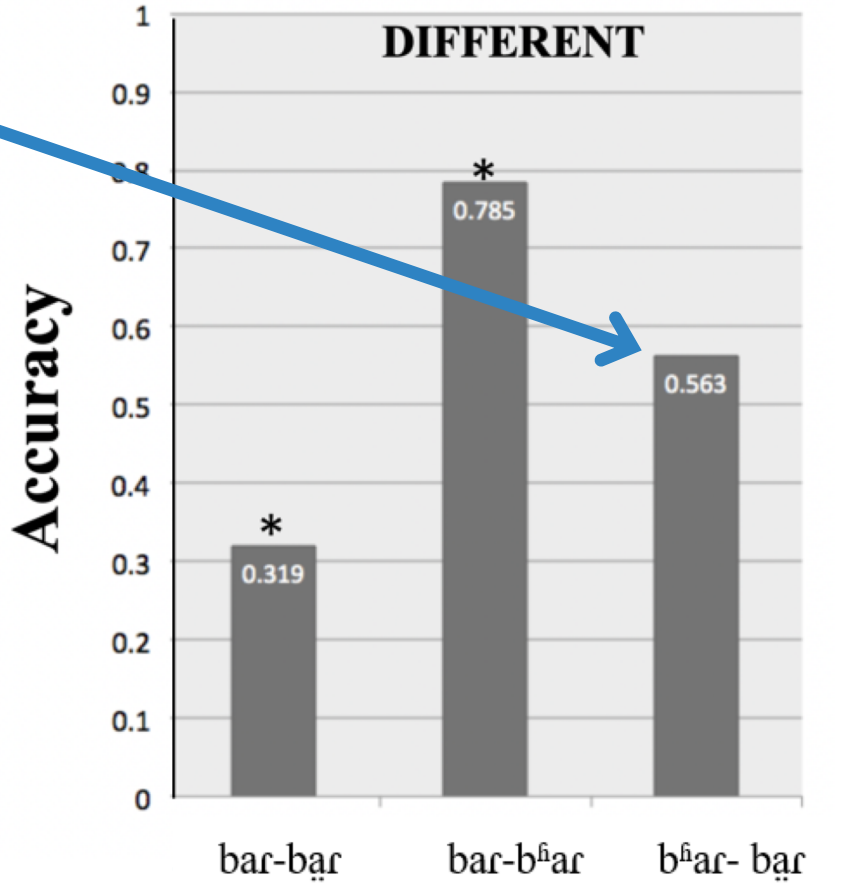
Task 2: AX discrimination

- In "different" trials:
  - [baɾ]-[bʱaɾ] was "different"



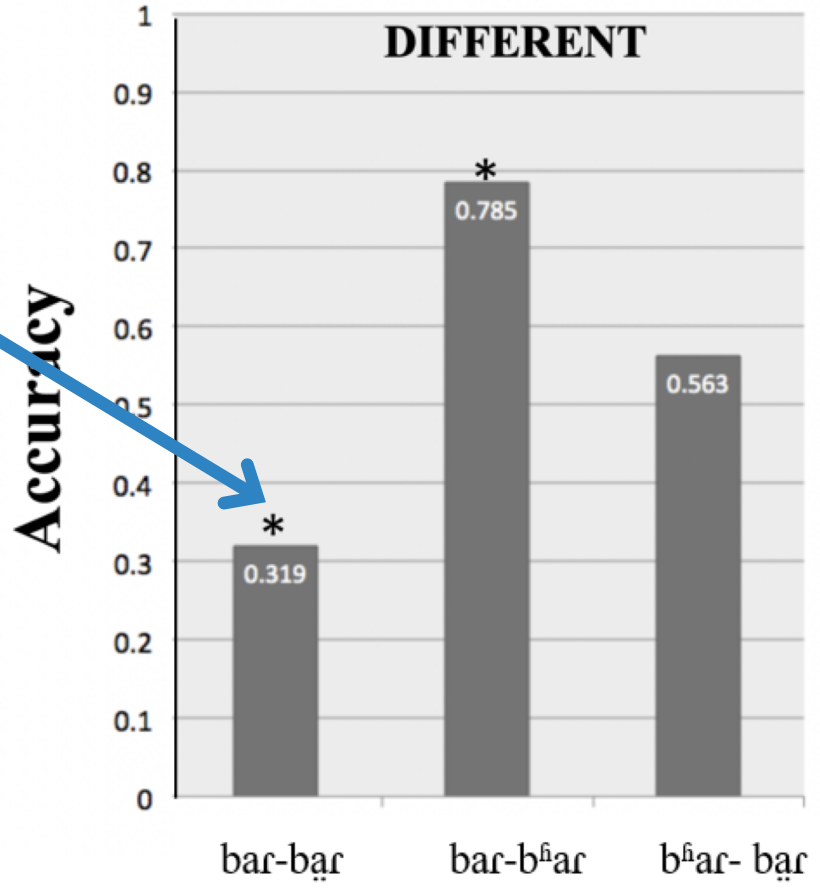
Task 2: AX discrimination

- In "different" trials:
  - [baɾ]-[bʱaɾ] was "different"
  - [baɺɾ]-[bʱaɾ] was not sig. different from chance



Task 2: AX discrimination

- In "different" trials:
  - [baɾ]-[bʱaɾ] was "different"
  - [baɺɾ]-[bʱaɾ] was not sig. different from chance
  - [baɺɾ]-[baɾ] was "same"!
- Suggests overlap of [baɺɾ] with [bʱaɾ], and merger with [baɾ]



Task 3: picture-matching

- **ID task with images** representing words
  - Audio followed by image
  - Clicked સરખું ‘same’ or જુદું ‘different’
  - This was the task most strongly determined by lexical categories

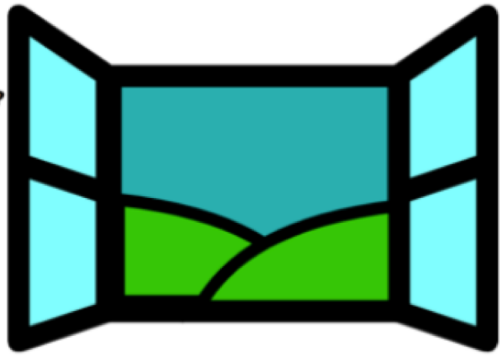
All modal
[baɾ] **‘twelve’**

‘twelve’

Breathy Cʱ
[bʱaɾ] **‘burden’**

‘burden’

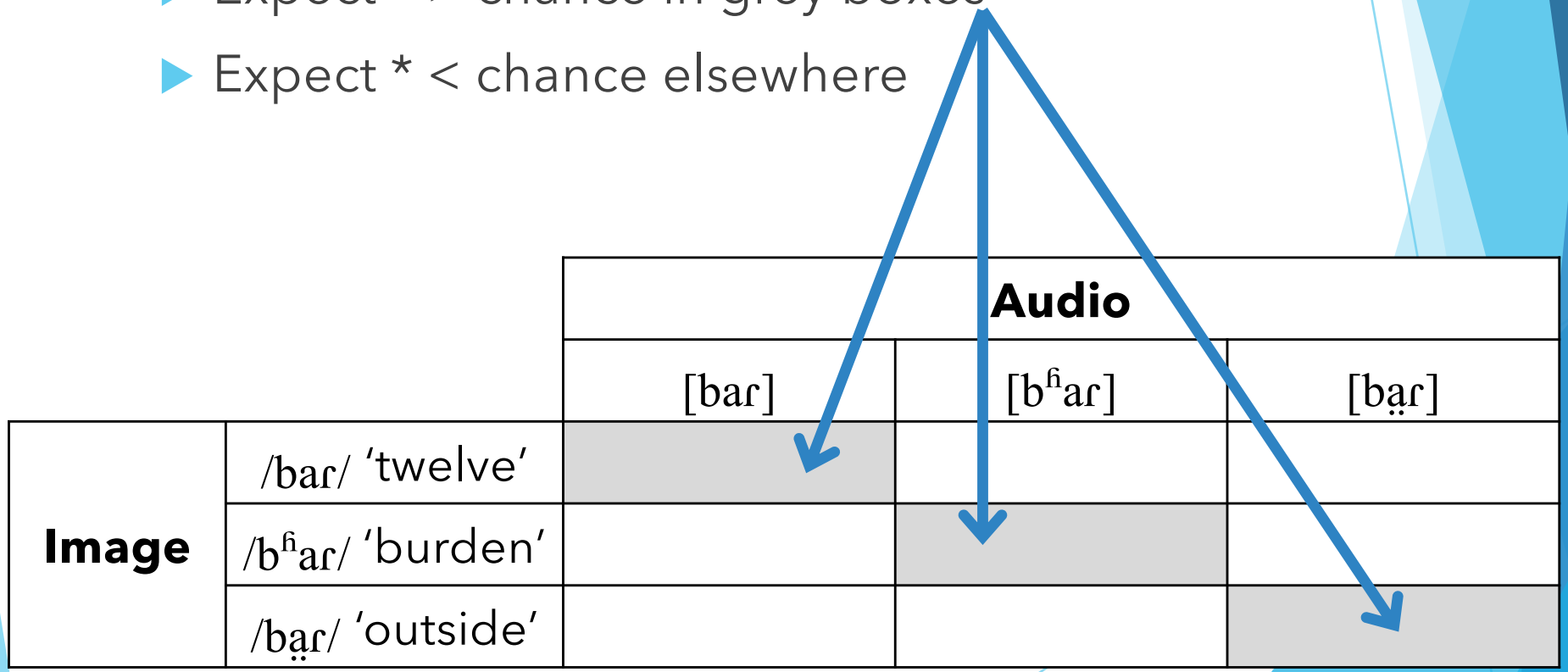
Breathy V̤
[bə̤ɾ] **‘outside’**



‘outside’

Task 3: picture-matching

- Results in the form of a confusion matrix
- If listeners are great at this task:
  - Expect * > chance in grey boxes
  - Expect * < chance elsewhere



		Audio		
		[baɾ]	[bʱaɾ]	[bạɾ]
Image	/baɾ/ ‘twelve’			
	/bʱaɾ/ ‘burden’			
	/bạɾ/ ‘outside’			

Task 3: picture-matching

- [baɾ] and [bʱaɾ] were robust, distinct groups
  - Audio+image matches consistently accepted
  - Mismatches consistently rejected

		Audio		
		[baɾ]	[bʱaɾ]	[bạɾ]
Image	/baɾ/ ‘twelve’	97.5*	5.0*	
	/bʱaɾ/ ‘burden’	17.5*	70.0*	
	/bạɾ/ ‘outside’			

Task 3: picture-matching

- [bạɾ] however, was problematic throughout
- Listeners did not consistently accept or reject any audio paired with /bạɾ/ image

		Audio		
		[baɾ]	[bʱaɾ]	[bạɾ]
Image	/baɾ/ ‘twelve’	97.5*	5.0*	70.0* !
	/bʱaɾ/ ‘burden’	17.5*	70.0*	22.5*
	/bạɾ/ ‘outside’	65.0	42.5	62.5

Task 3: picture-matching

- Listeners rejected [bạɾ] audio for /bʱaɾ/ image
- They accepted [bạɾ] audio for /baɾ/ image (!)
- And they were inconsistent about whether [bạɾ] audio matched the /bạɾ/ image itself

		Audio		
		[baɾ]	[bʱaɾ]	[bạɾ]
Image	/baɾ/ ‘twelve’	97.5*	5.0*	70.0* !
	/bʱaɾ/ ‘burden’	17.5*	70.0*	22.5*
	/bạɾ/ ‘outside’	65.0	42.5	62.5

Summary of results

- **Two robust categories**
- All modal [bɑɾ]:
  - fairly consistently grouped in free-sort
  - 87.5% “same” in audio pairs
  - 97.5% “same” when paired with own image
- Breathy consonant [bʱɑɾ]:
  - very consistently grouped in free-sort
  - 83.3% “same” in audio pairs
  - 70.0% “same” when paired with own image

Summary of results

- **One robust contrast**
- [baɾ] vs. [bʱaɾ]:
  - rarely grouped in free-sort
  - 78.5% “different” in audio pairs
  - 82.5% “different” w/ opposite image

Summary of results

- **One poorly-defined category**
- Breathy vowel [bạ̈ɾ]:
  - most inconsistently sorted
  - neither “same” nor “different” in audio pairs
  - neither “same” nor “different” w/ own image

Summary of results

- **Two poorly-defined contrasts**
- [bạɾ] vs. [bʱaɾ]:
  - rarely collapsed in free-sort
  - BUT inconsistent responses for audio pairs
- [bạɾ] vs. [baɾ]:
  - most likely to collapse in free-sort
  - 68.1% "same" in audio pairs
- Directionality: [bạɾ] audio rejected for /bʱaɾ/ image, and accepted for /baɾ/ image… but inconsistent responses for inverse pairings

Conclusions

- Gujarati spkrs produce a 3-way breathiness distinction, but they **do not reliably perceive it**
- **Subtle, constant breathiness** of CV̤ is **missed**
- **Robust, brief breathiness** of C$^{\text{ɦ}}$V is perceived…
- …but is often **mis-associated to** CV̤
- **New question:** how are they producing this contrast if they aren't clearly perceiving it?
- More data is needed
- Before expanding study further, we'd love to hear your feedback!

Acknowledgments

- To my co-authors, our talkers, our listeners, and to everyone in the audience here at ICPhS-19:

[abʱar]

આભાર

‘thanks’

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Gujarati breathiness

- 4-way contrast in **consonantal glottal state**

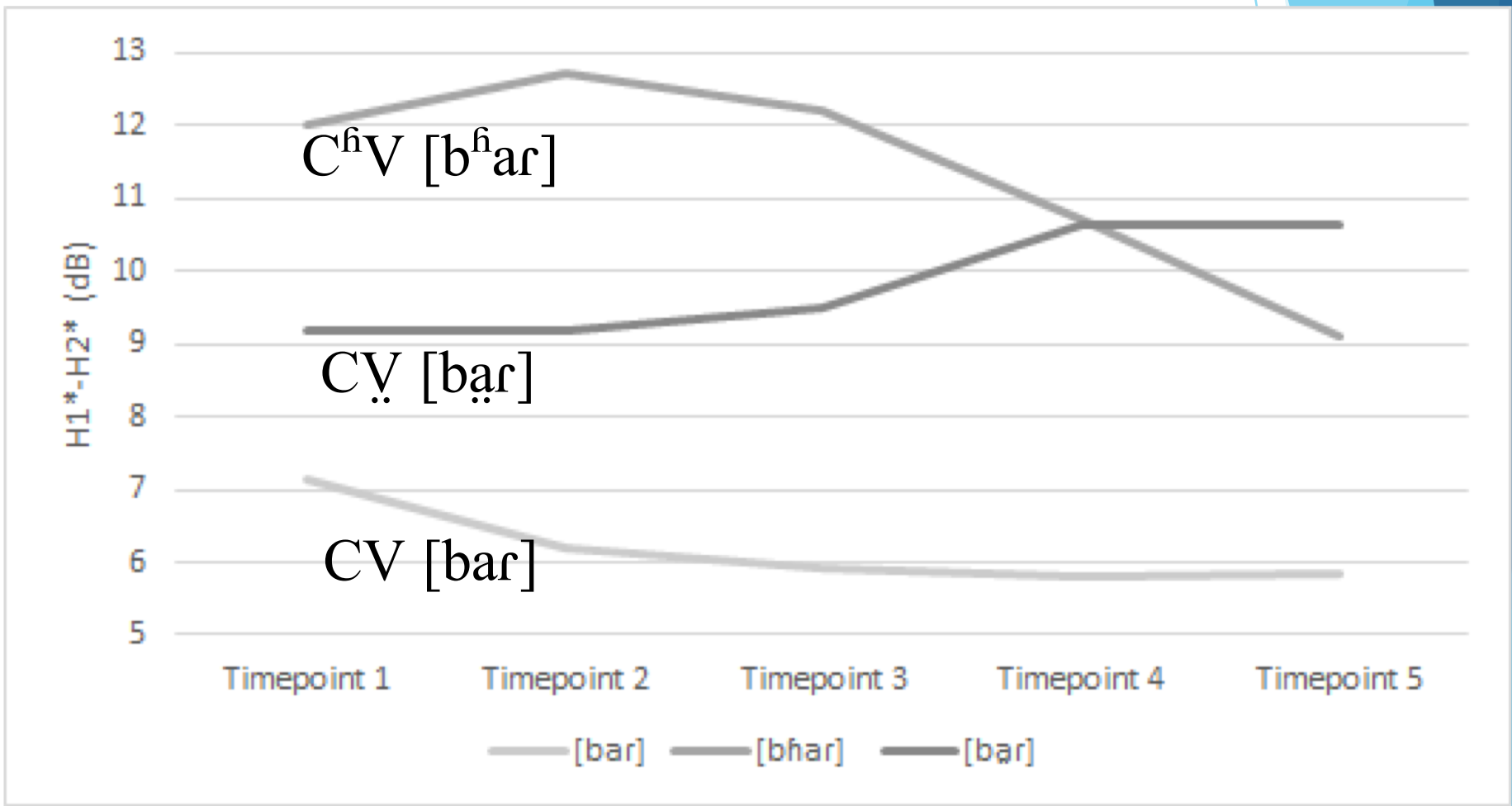
	Orthography	IPA	Gloss
-voi -asp	કાલ	kal	‘yesterday/tomorrow’
-voi +asp	ખાળ	k^{h}al	‘drain’
+voi -asp	ગાળ	gal	‘curse word’, ‘filter!’
+voi +asp	ઘાલ	$g^{ɦ}$al	‘penetrate!’

- 2-way contrast in **vocalic glottal state**

	Orthography	IPA	Gloss
modal	કાન	kan	‘ear’
breathy	કહાન, કહાનો	kn̤(o)	‘Krishna’

Predictions

- Distinguishing CV, C^{ɦ}V, CV̤ using H1–H2



Why just these target words?

- Task might be difficult enough, so a minimal triplet is desirable
- Roughly equal lexical frequency
- /ɓ/ → [ɓ̈] optionally before modal but not breathy Vs, which can aid listeners (Vyas 1978)
- Breathiness is most perceptible in low /a̤/ (Fischer-Jørgensen 1967)
- Mid /e̤ o̤/ tend to lower to /ɛ̤ ɔ̤/ when breathy (Dave 1967)