Perception of sibilant geminates by non-native listeners

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Geminates: long consonants

E.g., be**ll**o ‘beautiful’ be**l**o ‘I bleat’ (Italian)

ta**kk**a ‘fireplace’ ta**k**a- ‘back’ (Finnish)

- 1.5-3 times as long as singletons

  (Ladefoged & Maddieson 1996)

- Distinguished mainly by **duration**

  but also: burst, VOT, amplitude, etc.

  (Lahiri & Hankamer 1988, Abramson 1986, 1992, 1999, Arvaniti 2001, Muller 2001)

Typology of geminates

- Cross-linguistically, the most common context for geminates is:

V_V

(Thurgood 1993)

Non-intervocalic geminates

- Examples:
  - Taba: ***tanggal*** ‘date’ (Bowden 2001: 39)
  - Cypriot Greek: ***ppefto*** ‘I fall’ (Arvaniti 2001: 23)
  - Palestinian Arabic: **ʔimm** ‘mother’ (Abu Salim 1980: 6)
  - Moroccan Arabic: ***ttlata*** ‘Tuesday’ (Heath 1987: 38)

Typology of geminates

- Survey of 40 languages with geminates:

	CONTEXT		
	intervocalic	one-sided vowel-adjacent	non-vowel-adjacent
Number of languages with geminates in a particular context *N = 40*	38	35 *word-initial:* 30 *word-medial:* 11 *word-final:* 6	4

- Implicational universal: (Thurgood 1993)

  non-intervocalic geminates > intervocalic geminates

Why are non-intervocalic geminates avoided?

- Restrictions on syllable structure?
  - But there are languages with very permissive syllable structure that avoid non-intervocalic geminates (e.g., Polish)

z-bʒdɛ̃kʲɛm	'with a plunk'
*z-znɑkʲɛm	'with a sign'

Why are non-intervocalic geminates avoided?

- Hypothesis:
  - Perceptually-based markedness hierarchy

non-vowel-adjacent > single vowel-adjacent > intervocalic

#GGC, CGG#, CGGC #GGV, VGG#, VGGC, CGGV VGGV

  - Non-intervocalic geminates are marked because they are perceptually less salient

Experiments: goals

- Investigate the acoustics of VGGV vs. non-VGGV
- Check how non-native listeners perceive the gem-sing contrast in V_V vs. non-V_V contexts
- Support / reject the hypothesis that the markedness hierarchy is perceptually based

Experiment 1: Acoustics

- Testing the geminate-singleton contrast for coronal fricatives ([ss]~[s] / [zz]~[z])
- 4 conditions:

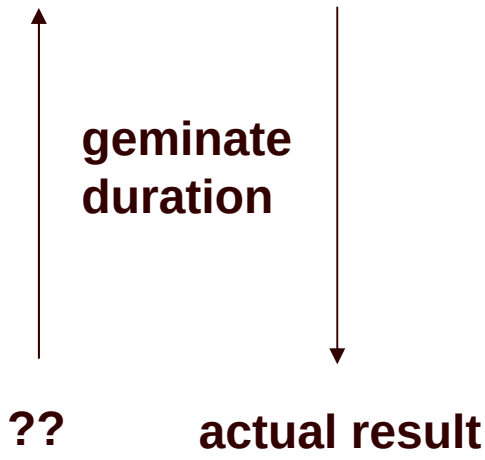
POSITION IN A WORD	FOLLOWING SEGMENT	
	VOWEL	CONSONANT
MEDIAL	[assa] ~ [asa] [azza] ~ [aza]	[assta] ~ [asta] [azzda] ~ [azda]
INITIAL	[ssa] ~ [sa] [zza] ~ [za]	[ssta] ~ [sta] [zzda] ~ [zda]

- Test words recorded by a native Moroccan Arabic speaker (all the sequences are phonotactically legal in Moroccan Arabic)
- 18 repetitions for each condition (recorded with fillers, in three separate sessions)

Predictions

- If non-V_V geminates are less perceptible than V_V geminates, maybe it's because non-V_V geminates are shorter in duration

medial+V	[assa], [azza]
medial+C	[assta], [azzda]
initial+V	[ssa], [zza]
initial+C	[ssta], [zzda]



Results: fricative durations

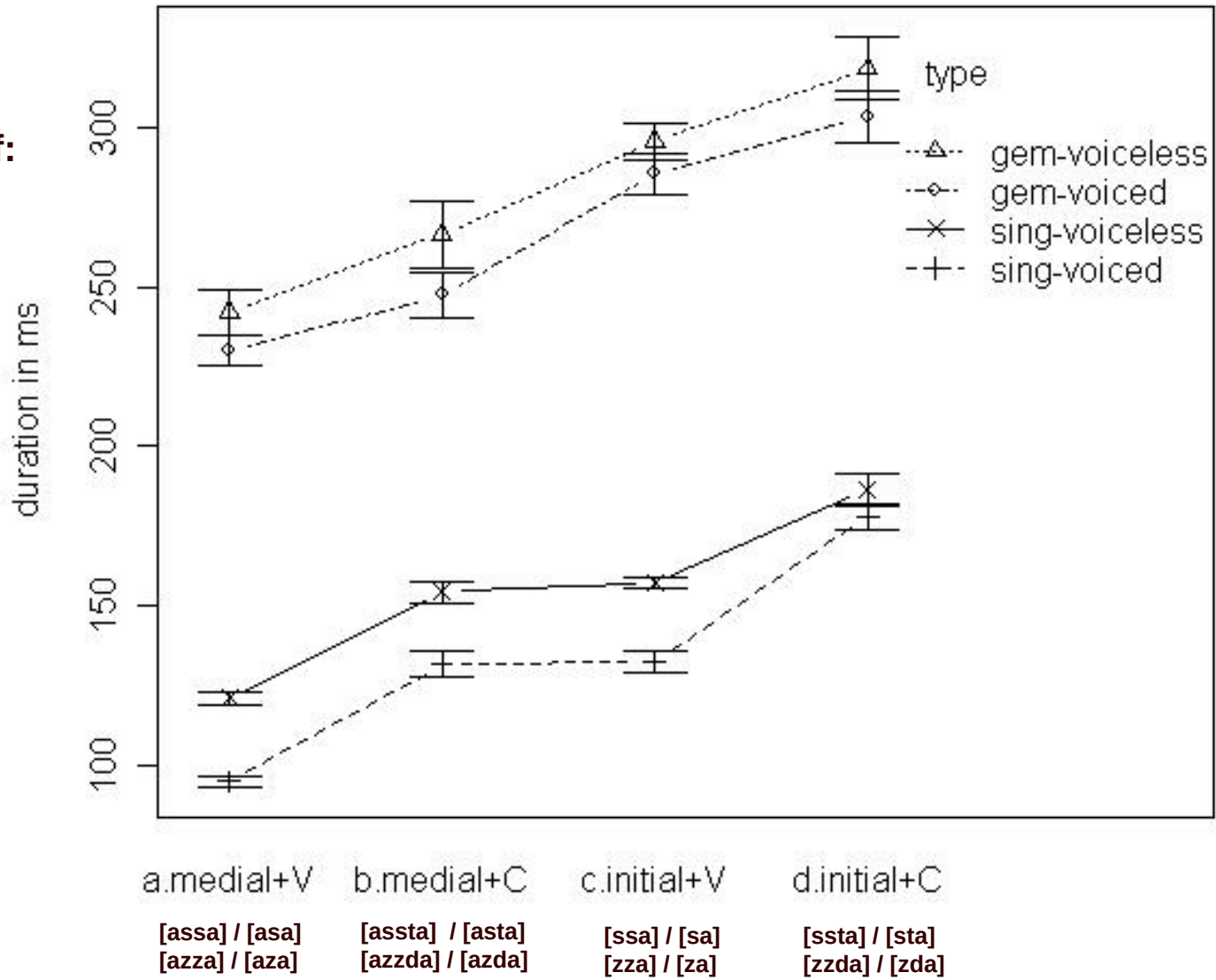
ANOVA
Significant effect of:

-type (gem/sing) (p<.001)

-voicing (voiced/voiceless) (p<.001)

-position (medial/initial) (p<.001)

-following segment (vowel/consonant) (p<.001)



Results: fricative durations

Mean durations (in ms)

type		*condition*			
		Medial+V	Medial−C	Initial+V	Initial−C
geminate	*voiceless*	242 (se=7)	266 (11)	296 (6)	318 (10)
	voiced	230 (5)	248 (7)	286 (6)	303 (8)
singleton	*voiceless*	121 (2)	154 (4)	157 (2)	186 (5)
	voiced	95 (2)	131 (4)	132 (4)	178 (4)
geminate/singleton ratio	*voiceless*	2.0	1.7	1.9	1.7
	voiced	2.4	1.9	2.2	1.7

- Initial geminates are longer than medial geminates
  - Should their perception be easier? Or is longer duration an attempt to compensate for their poorer perceptibility?
- The gem/sing duration ratio is lower when the following segment is a consonant than if it is a vowel
  - Does it make the gem/sing contrast in that context more difficult to hear?

Experiment 2: Perception

- Method: AX discrimination task

	‘different’ pairs	‘same’ pairs
e.g.	$[assa]_1$~$[asa]_1$	$[assa]_1$~$[assa]_2$
	$[asa]_1$~$[assa]_1$	$[asa]_1$~$[asa]_2$

  - 6 repetitions of a block:

    64 word pairs (32 test pairs + 32 fillers)

  - Each subject heard 12 repetitions of each test condition

Participants

- 34 undergraduate students at UCSD:
  - native speakers of English
  - with at most limited exposure to languages that use geminates contrastively (German, Japanese, Korean)

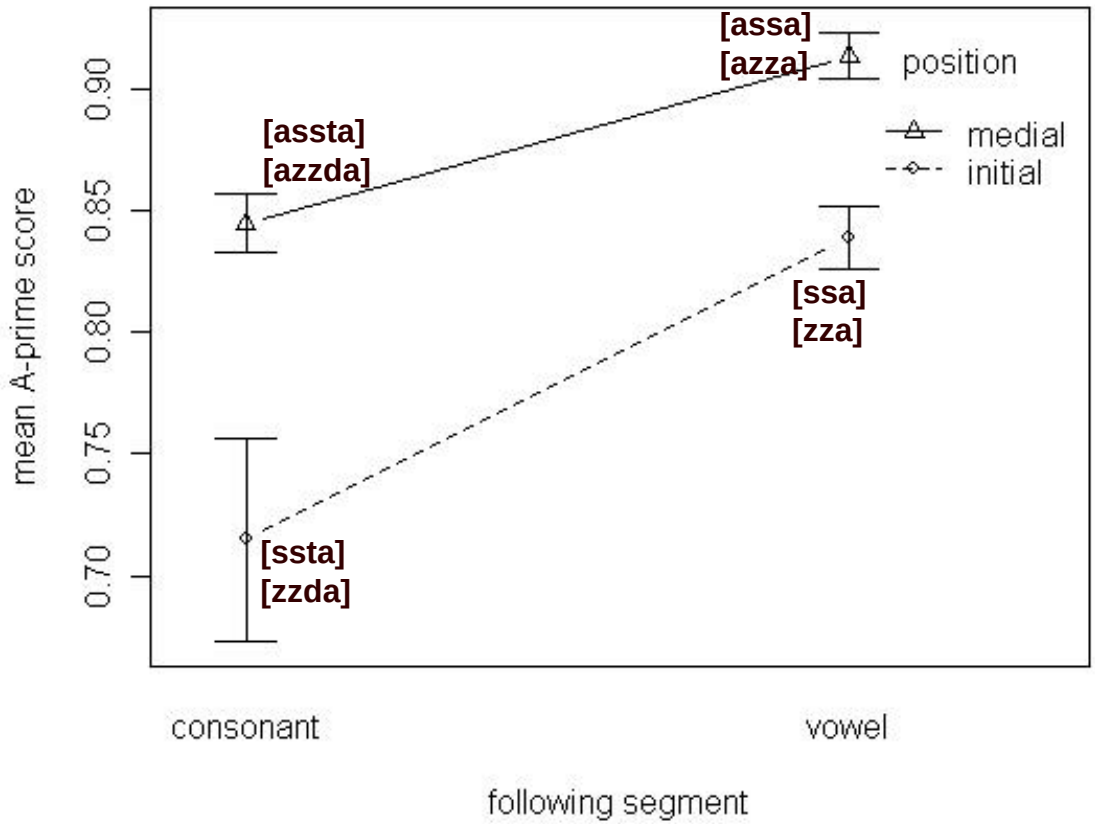
Predictions

- Predictions:
  - better performance with ‘medial’ tokens than with ‘initial’ tokens
  - better performance with ‘+V’ tokens than ‘+C’ tokens

Results

- ANOVA: significant effect of *position* (p<.001) and *following segment* (p<.001)

Mean A-prime scores:



Subjects discriminated between the gem/sing contrast:

-better in medial than in initial position

-better when the following segment was a V than when it was a C

Potential issues

- Only two different tokens were used for each condition
- The role of adjacent vowels requires further investigation

Experiment 3: Perception

- All the tokens have spliced vowels:

  4 versions of the experiment

  - A: $_{gem}$[a]ss[a]$_{gem}$ $_{sg}$[a]s[a]$_{sg}$ ‘matching vowels’
  - B: $_{sg}$[a]ss[a]$_{sg}$ $_{gem}$[a]s[a]$_{gem}$ ‘non-matching vowels’
  - C: $_{gem}$[a]ss[a]$_{gem}$ $_{gem}$[a]s[a]$_{gem}$ ‘geminate vowels’
  - D: $_{sg}$[a]ss[a]$_{sg}$ $_{sg}$[a]s[a]$_{sg}$ ‘singleton vowels’

Experiment 3: Perception

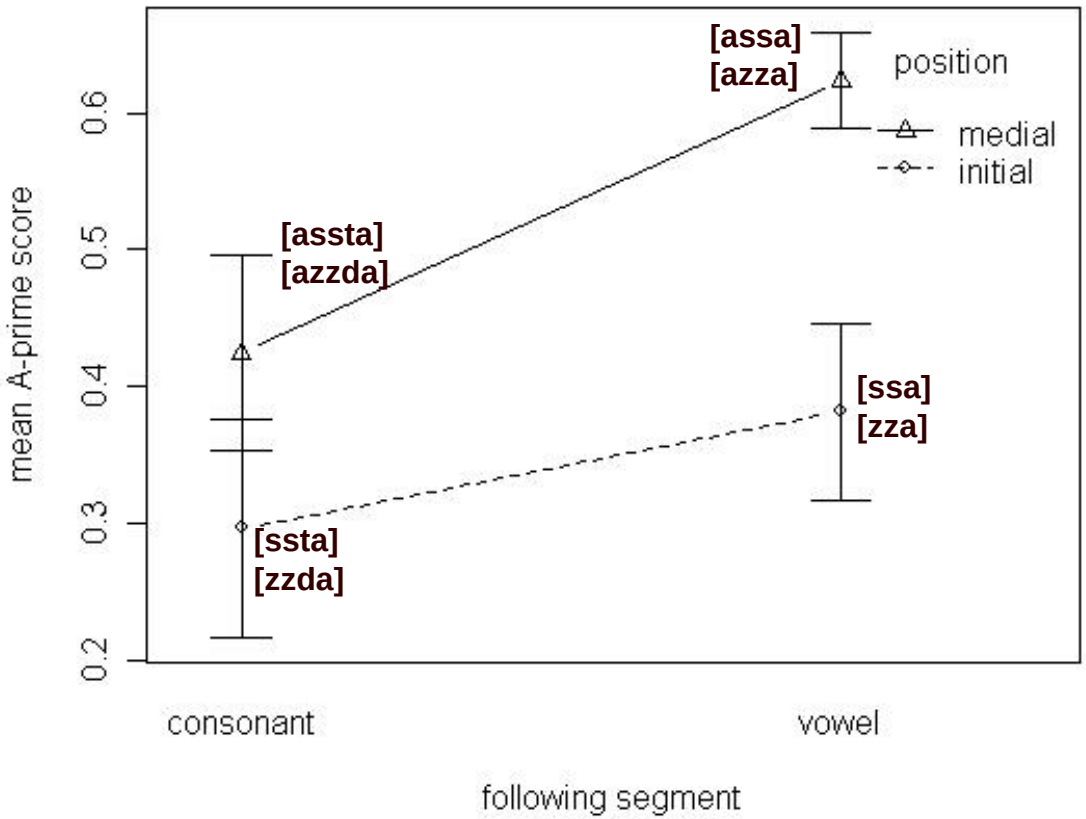
- Introducing variation
  - For each condition, 5 different tokens were chosen for splicing (5 for fricatives and 5 for vowels)
  - In each version of the experiment, 10 different combinations of spliced fricatives and vowels were created
  - Each subject listened to 4 different combinations of tokens (repeated 3 times)

Predictions: ‘matching vowels’

- Repetition of the results from the previous experiment, that is:
  - better performance with ‘medial’ tokens than with ‘initial’ tokens
  - better performance with ‘+V’ tokens than ‘+C’ tokens

Preliminary results: 'matching vowels' (subjects=19)

- Significant effect of *position* (p<.05) and *following segment* (p<.01)



Subjects discriminated between the gem/sing contrast:

-better in medial than in initial position

-better when the following segment was a V than when it was a C

Why are non-intervocalic geminates less perceptible?

- The effect of *following segment*:
  - The gem/sing contrast is less perceptible when the following segment is a C than when it is a V
  - Explanation: the gem/sing duration ratio is lower in '+C' contexts than in '+V' contexts
    (i.e., the geminates and the singletons are closer together in duration in the '+C' contexts)

Why are non-intervocalic geminates less perceptible?

- The effect of *position*:
  - The gem/sing contrast is less perceptible in the initial than in the medial position
  - Tentative explanation: influence of the following vowel

Differences in vowel durations

- **'Medial' tokens:** final vowel is the same in gem words than in sing words

Mean duration:	**265ms** (se=7)	**273ms** (6)
	assa	asa
	assta	asta
Mean duration:	**295ms** (7)	**289ms** (8)
	azza	aza
	azzda	azda

- **'Initial' tokens:** final vowel is shorter in gem words than in sing words ($p<.001$) (minimal word effect?)

Mean duration:	**273ms** (7)	**300ms** (7)
	ssa	sa
	ssta	sta
Mean duration:	**297ms** (8)	**332ms** (9)
	zza	za
	zzda	zda

Identifying geminate boundaries

- Using intensity jumps as a cue
  - The boundaries identified:

more easily | less easily | (e.g., Kawahara 2007)

a kk a

a ll a

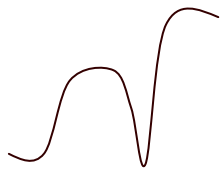
- What about these?

a ss a

a ss t a

ss a

ss t a



Conclusion & future direction

- **Position** in a word and the nature of the **following segments** influence the perception of the gem-sing contrast
  - in a way that is **consistent with typological distribution of geminates**
- Therefore, there is initial support for the claim that the contextual markedness hierarchy has **perceptual basis**
- Future work:
  - Further investigation of the acoustics and the perception of geminates, varying the segments and the exact context

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