



# Plasticity in bilingual speech perception and production

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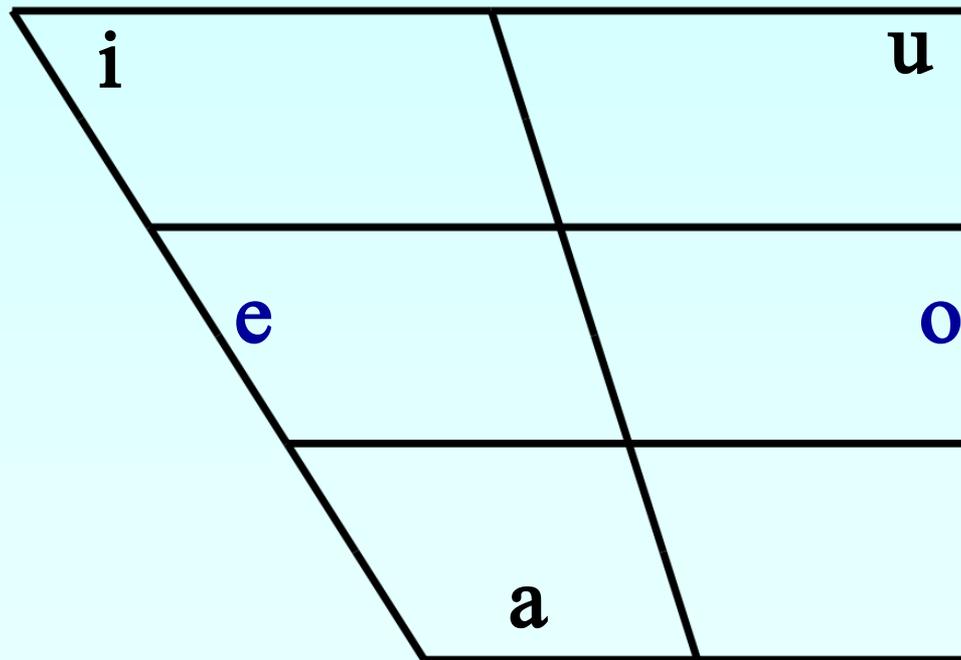
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## Introduction: mid vowels in Spanish and Catalan

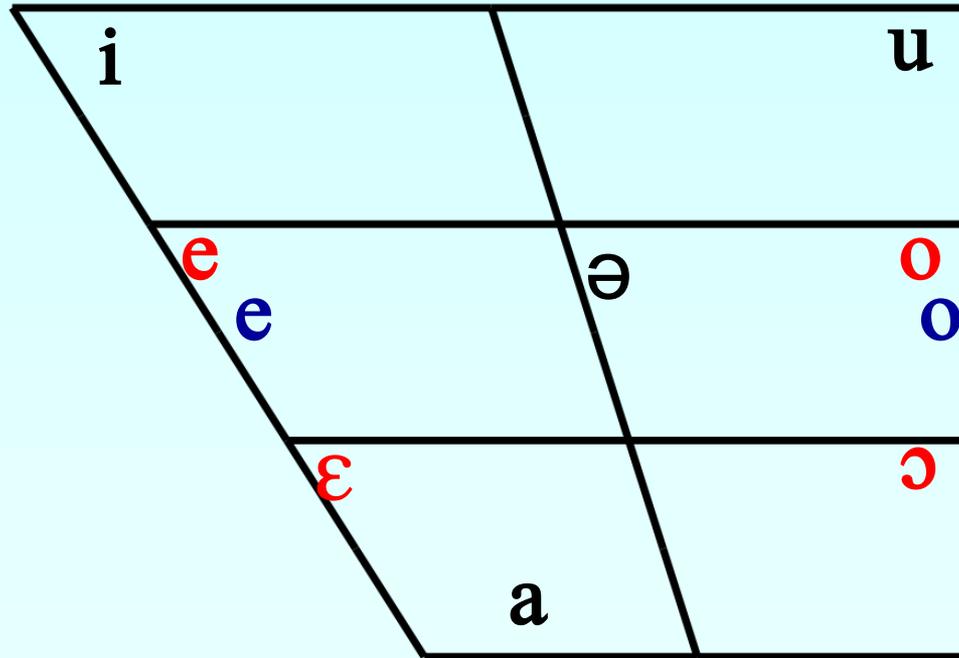
- Spanish:**
- 5 vowel system
  - 3 corner vowels: /i/, /a/, /u/
  - 2 mid vowels: /e/ and /o/





# Introduction: mid vowels in Spanish and Catalan

- Catalan:**
- 8 vowel system
  - 3 corner vowels: /i/, /a/, /u/
  - 1 unstressed central vowel: /ə/
  - 4 mid vowels: */e/-/ɛ/* and */o/-/ɔ/*





## Introduction: mid vowels in Spanish and Catalan

This is a difficult situation for the Spanish learner of Catalan:

### Spanish /e/:

- lies between Catalan /e/-/ɛ/
- has allophones similar to each Catalan vowel:  
*lejos* “far” /'lɛxos/ vs. *lento* “slow” /lento/
- appears in Catalan cognates in place of either vowel:

*maleta* “suitcase” /ma'leta/ in Spanish

/ma'lɛtə/ in Catalan

*cartera* “wallet” /kar'tera/ in Spanish

/kər'terə/ in Catalan



## Introduction: mid vowels in Spanish and Catalan

This is a difficult situation for the Spanish learner of Catalan:

### Catalan /e/ and /ɛ/:

- low functional load (few minimal pairs)  
*nét* /net/ “grandson” vs. *net* /nɛt/ “clean”
- reduce to /ə/ in unstressed syllables:  
*pes* (n.) /pɛs/ “weight” > *pesar* (vb.) /pə'za/ “weigh”.  
but: “I weigh” is *peso* /'pezu/.
- tretze* /'tredzə/ “13” > *tretzè* /trəd'zɛ/ “13th”
- variation across and within dialects  
*res* /res/ - /rɛs/ “nothing”

Catalan /o/-/ɔ/ is similar to /e/-/ɛ/ (BUT neutralizes into /u/)

*gos* /gos/ “dog” > *goset* /guzɛt/ “little dog”  
*nou* /nɔw/ “9” > *novè* /nu'βɛ/ “9th”



## Introduction: Acquisition of Catalan mid vowel contrasts

**This is different from other well-studied cases of difficulty in the acquisition of L2 sound contrasts:**

**//-/r/ for Japanese learners of English**

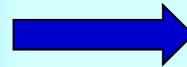
- **Very clear-cut case:** extremely difficult for Japanese speakers, completely natural for English speakers.
- **Acoustics:** large difference “rock” vs. “lock”
- **No risk of confusion by English speakers**

**BUT:** - hard to find true simultaneous bilinguals  
- most living in monolingual culture

- ≠ immersion settings (immigrant populations)
- ≠ FL setting (student populations AH or SA)



# Introduction: the bilingual context in Barcelona





## Introduction: the bilingual context in Barcelona

### Spanish

/i/      /u/

/e/      /o/

/a/

Catalan  
+  
Spanish

### Catalan

/i/      /u/

/e/      /o/

/ɛ/      /ɔ/

/a/

### Exposure:

- at home (monolingual)
- vs.
- school (bilingual)



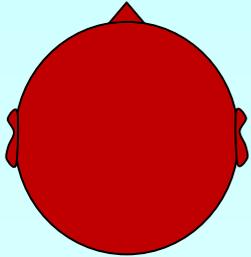
### Exposure:

- at home (bilingual)
- &
- school (bilingual)



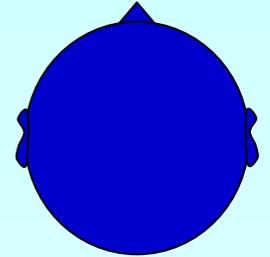
# Introduction: the bilingual context in Barcelona

**L1-Spanish**



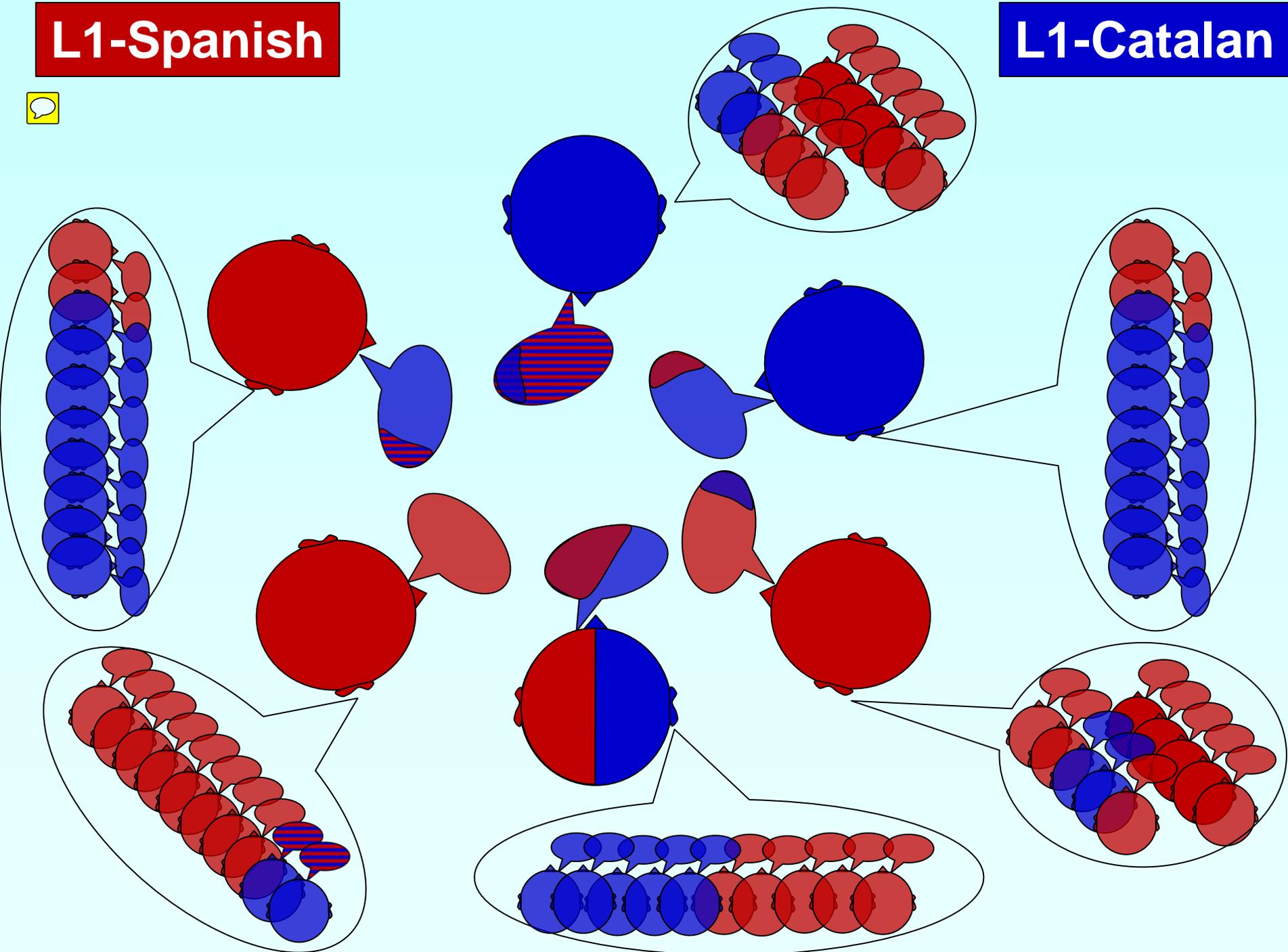
**BILINGUALISM**  
and  
Individual profiles of  
L1/L2 use

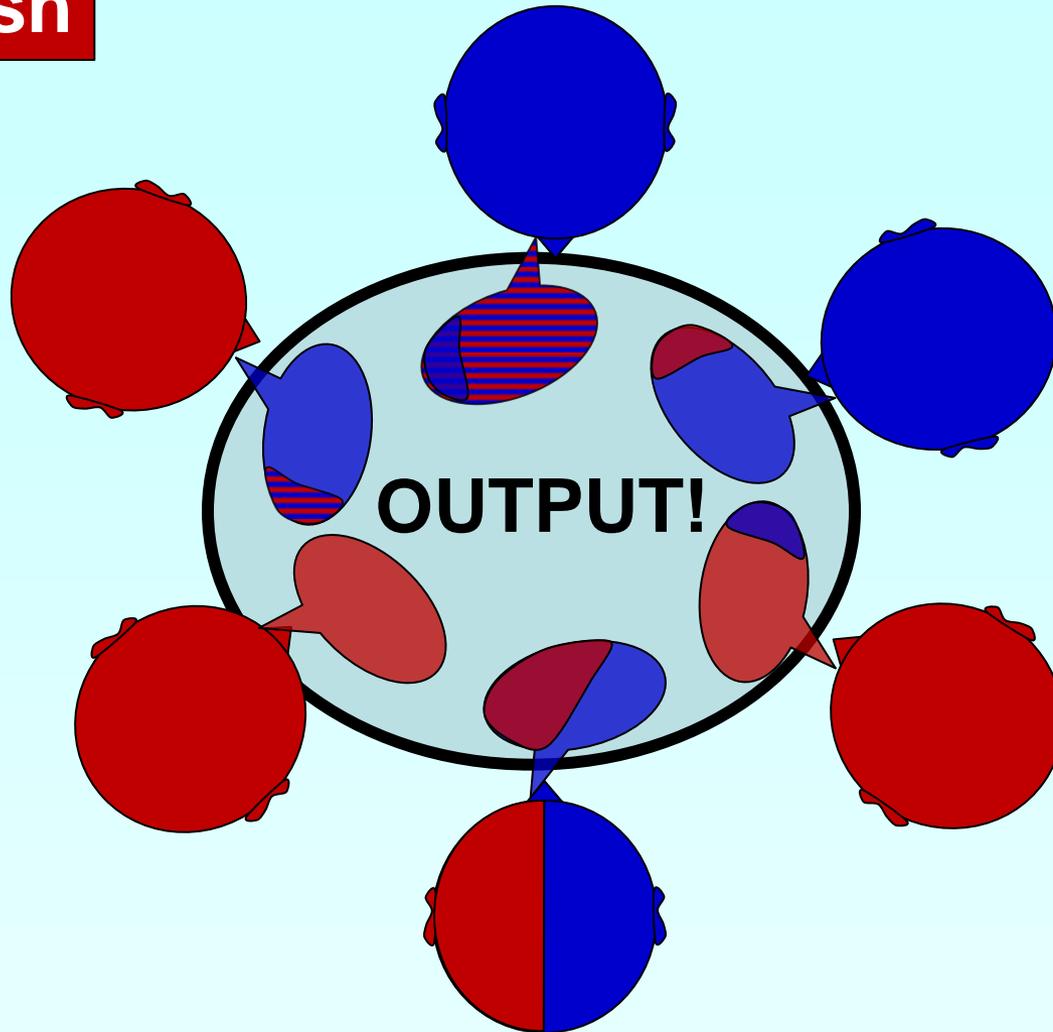
**L1-Catalan**



# L1-Spanish

# L1-Catalan





How good is this output for the L1-Spanish learner of Catalan to develop robust phonological representations?



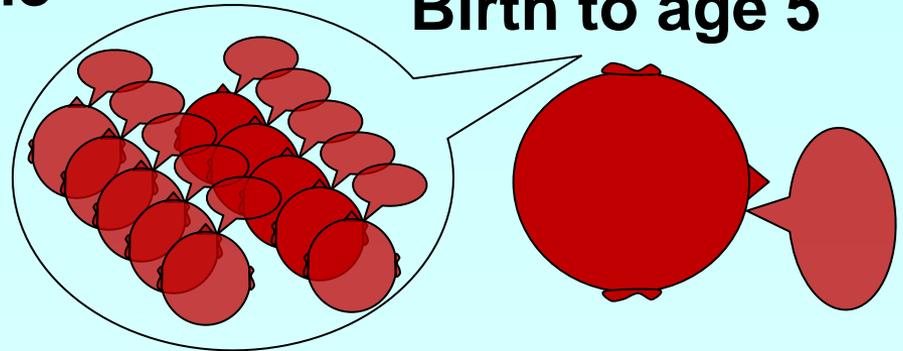
# Plasticity?

- Many different patterns of language use.
- Bilingualism as a **continuum** of L1 and L2 use.
- Patterns of L1 and L2 use are **unstable**.
- Speech input can be native-like or **accented**.
- Are phonological representations affected by language use?

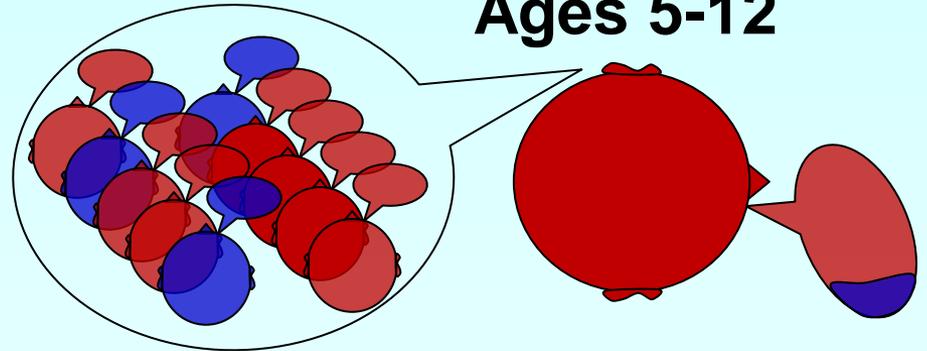
Time



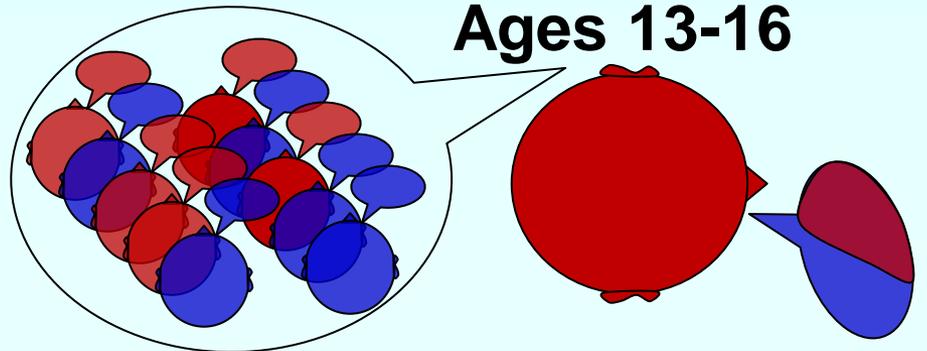
Birth to age 5



Ages 5-12



Ages 13-16

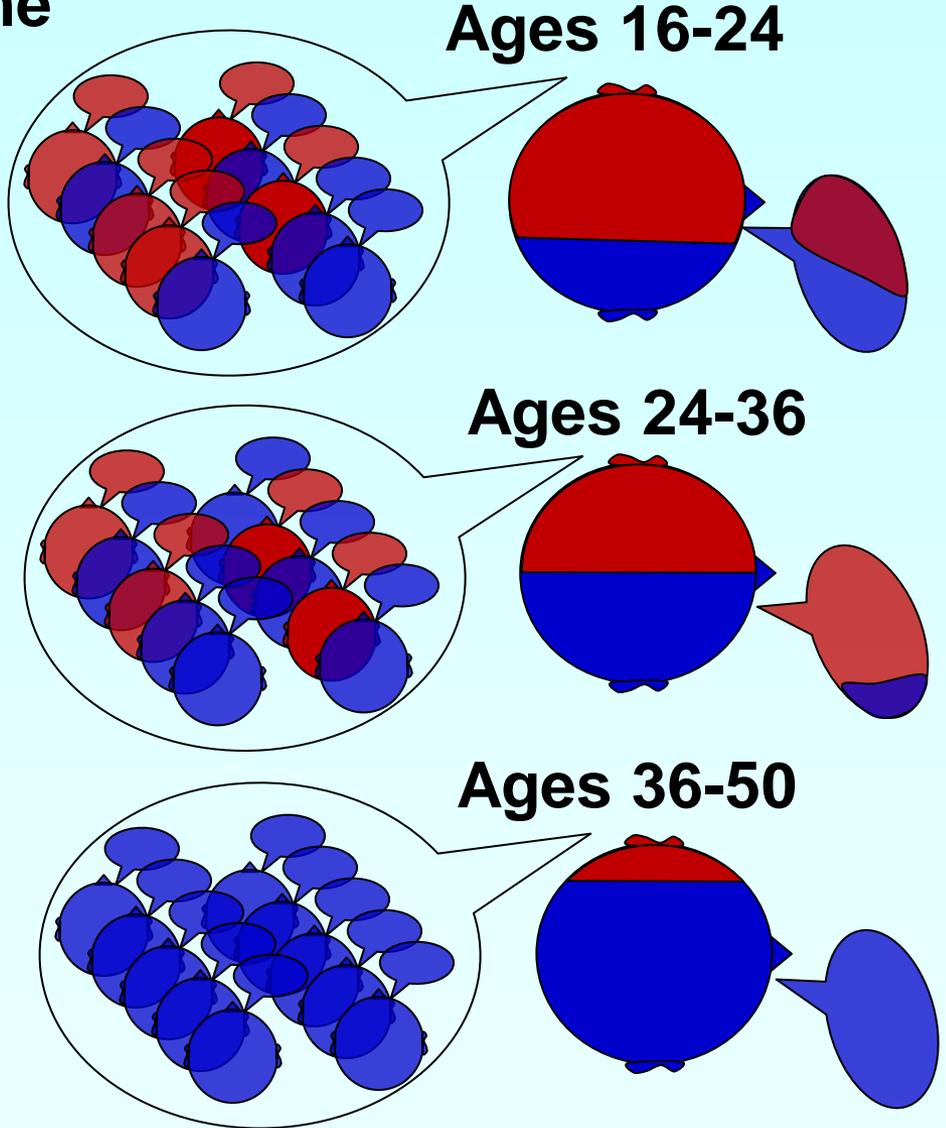




# Plasticity?

- Is the perceptual system malleable and sensitive to properties of the speech input?
- Can Spanish learners develop robust phonetic category representations for the Catalan mid vowels */e/*-*/ɛ/* and */o/*-*/ɔ/*?
- Are L1-Catalan representations modified due to Spanish-accented input?

Time



**- Methodological challenge!**



## Introduction: Acquisition of Catalan mid vowel contrasts

### Adult Catalan-Spanish bilinguals in Barcelona:

- Bilinguals are 1st exposed to L2 (Catalan or Spanish) as young children (early learners) at schooling age (3-6).
- Bilinguals may use both their languages daily in all contexts.
- Language dominance may not be stable over time.

### Bilingual learning in a language contact situation:

- Every permutation of bilingualism is represented.
- Allows for crucial tests of interaction between age of acquisition and eventual attainment.

# Previous research on the Catalan mid-vowels in BCN

(Sebastián-Gallés et al. 2005: study of early and simultaneous bilinguals)

## Lexical decision

- Early bilinguals: Catalan- or Spanish-dominant, highly proficient.

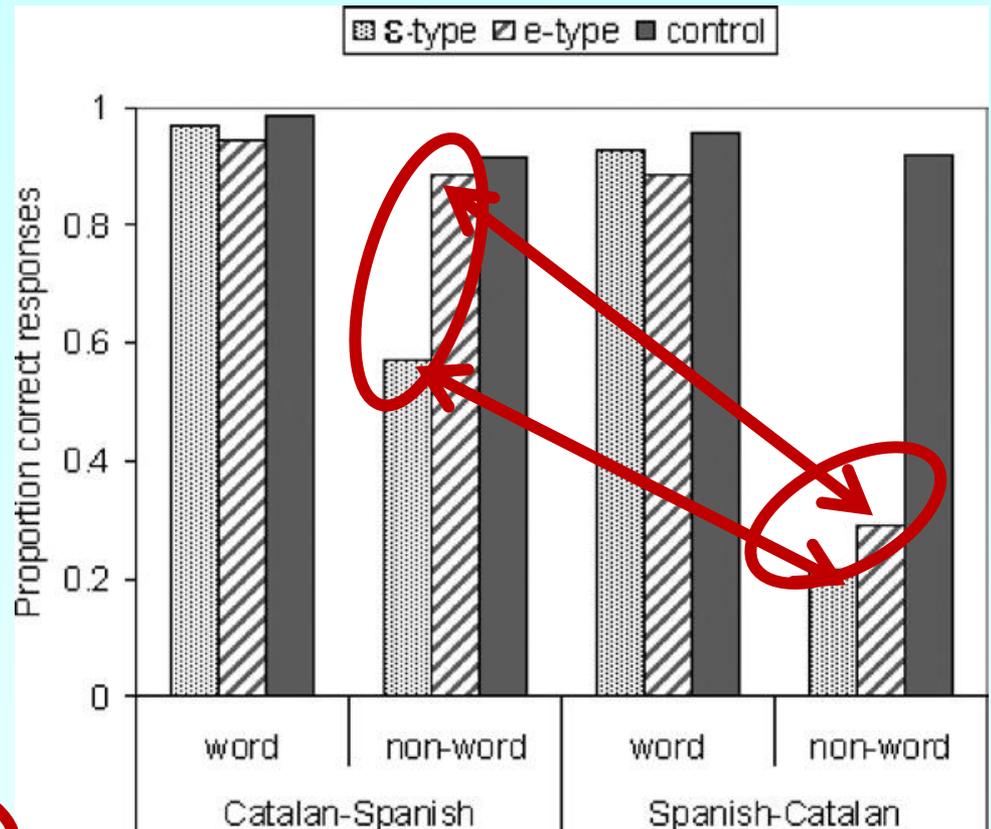
- Catalan words altered to nonwords via substitution of /e/ for /ɛ/ or vice-versa:

“**ɛ-type**” nonwords :

/fi'nestrə/ → \*/fi'ncstrə/

“**e-type**” nonwords:

/gə'λɛda/ → \*/gə'λeda/

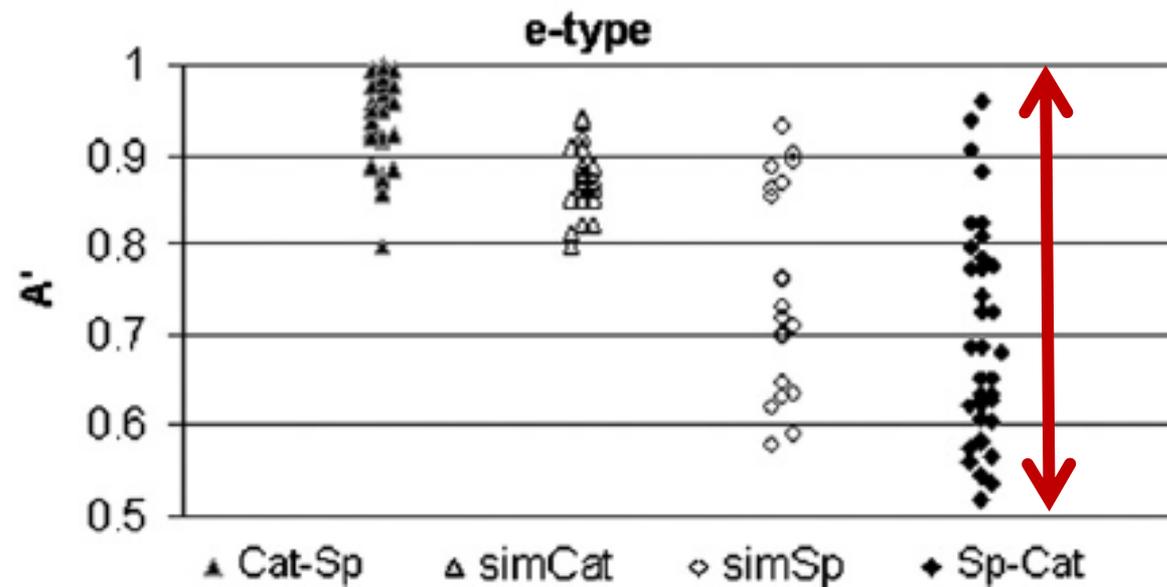
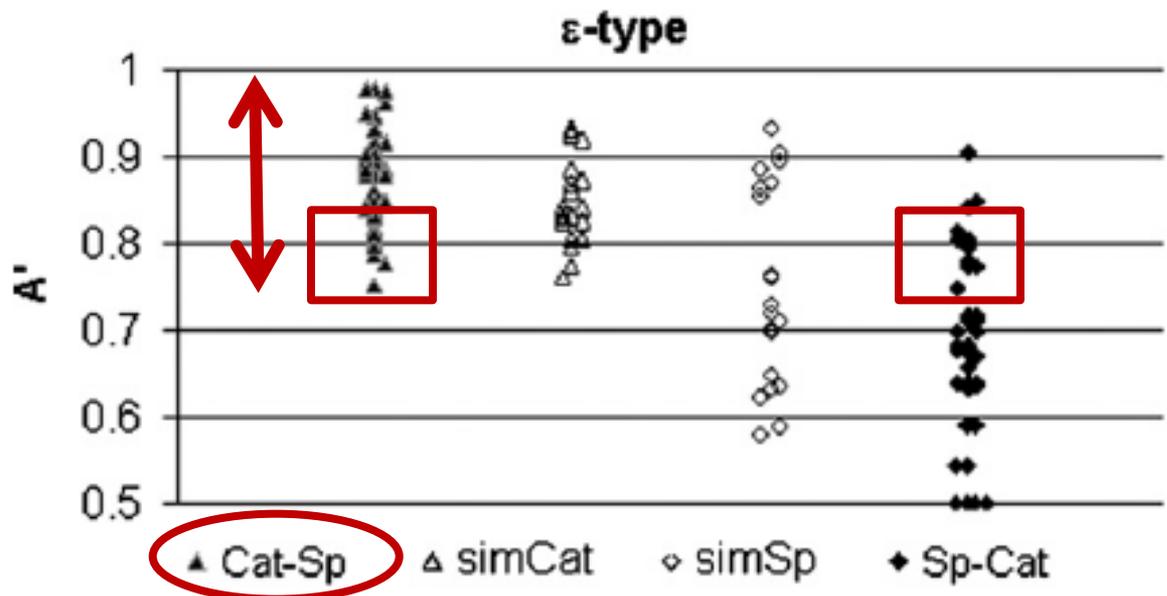


Catalan-dominant | Spanish-dominant

(Bosch, Costa & Sebastián-Gallés 2000; Pallier, Bosch & Sebastián-Gallés 1997; Sebastián-Gallés & Bosch 2005; Sebastián-Gallés, Echevarría & Bosch 2005; Sebastián-Gallés & Soto-Faraco 1999, among others)



# Previous research on the Catalan mid-vowels in BCN



- Clear decrease in performance

- Large variation even for Catalan-dominant early bilinguals.

- Asymmetry for Catalan-dominant bilinguals between  $\epsilon$ -type and e-type nonwords



# Previous research on the Catalan mid-vowels in BCN

## Interpretation:

### Differences between bilingual groups:

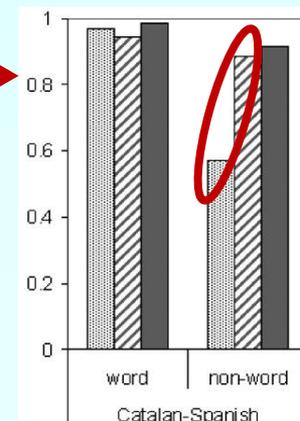
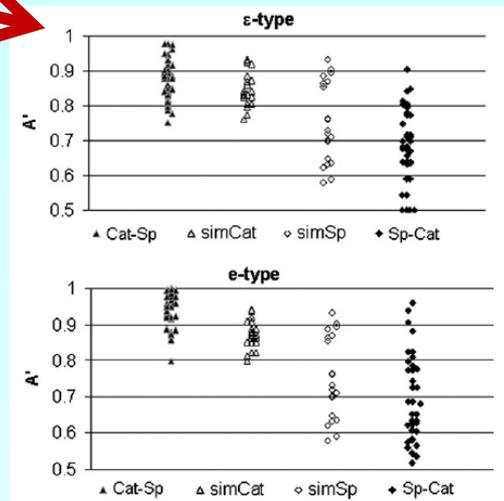
#### Developmental explanation

Phonemic categories acquired early in life compromise the acquisition of new phonetic categories later in life, despite early and extensive/intensive exposure to the L2.

### Asymmetries “ $\epsilon$ -type” vs. “e-type”:

#### Exposure to mispronunciations

Spanish speakers mispronounce Catalan *galleda* /gə'λɛda/ → \*/gə'λeda/





## Previous research on the Catalan mid-vowels in BCN

### Exposure to mispronunciations further investigated:

(Sebastián-Gallés et al. 2006, 2008; Larsson et al. 2008)

- ERP data for /di/-/de/-/dɛ/ syllables
- Neurodynamic modelling for phonemic and lexical processing:
  - phoneme discrimination task simulation
  - lexical decision task (LDT) simulation

### Findings:

- No evidence of perceptual difficulty with /e/ - /ɛ/.
- the “ɛ-type” vs. “e-type” asymmetry is replicated in LDT.

### CONCLUSION:

Lexical plasticity does NOT affect phonemic categories.

Bilinguals' lexicons store **canonical + accented** lexical representations (no effects at the phonetic level)



## 2 studies with bilingual populations in Barcelona

Investigate the robustness of the Catalan mid-vowel contrasts (are they phonetically “weak”?)

If so... does L1 & L2 use in a bilingual language contact context affect the perception and production of the mid vowel contrasts?

**Study 1:** (Mora, Keidel & Flege 2011, 2013 in press)

- bilinguals varying in degree of language dominance
- MostlySp, Sp-CatB, Cat-SpB, MostlyCat (L1-Sp + L1Cat)
- Perception and production of /e/-/ɛ/ and /o/-/ɔ/.

**Study 2:** (Mora & Nadeu 2012)

- Catalan-dominant bilinguals varying in amount of L1-Cat use
- Low (40-70%) vs. High (80-100%) (L1-Cat)
- perception and production of /e/-/ɛ/.



# Study 1: Participants

## Participants (Adult Catalan-Spanish bilinguals)

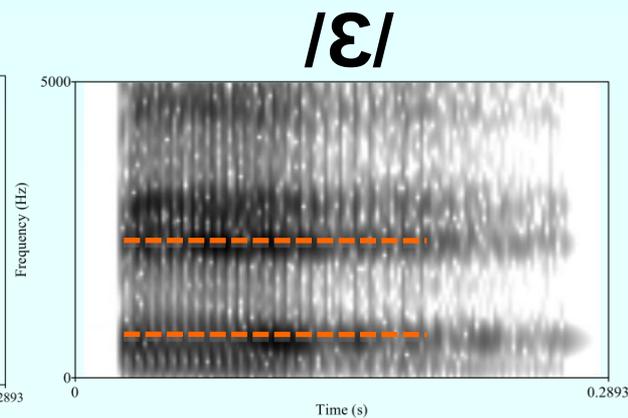
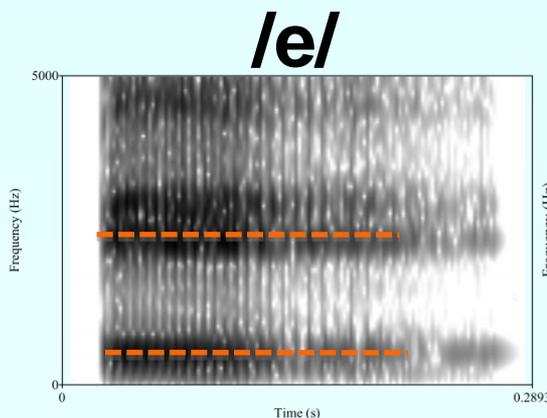
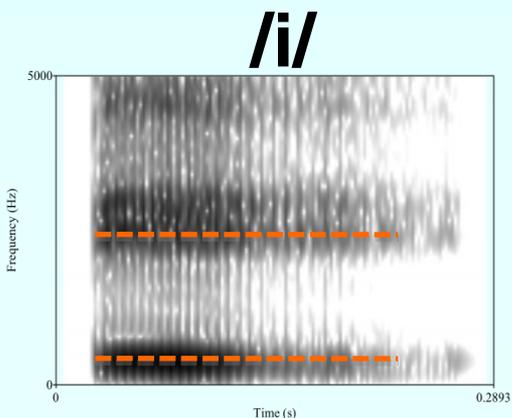
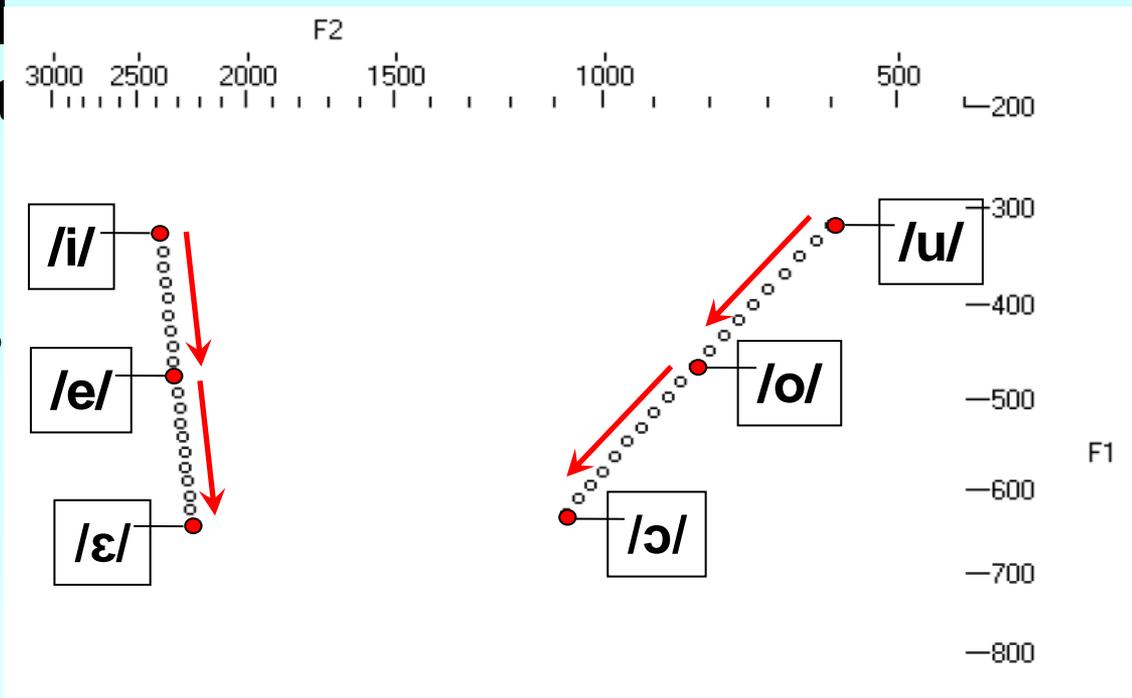
- **$N=715 > N=82$**  (after screening/selection: interview/questionnaire)
- First exposed to their L2 at around schooling age
- Born and raised in Barcelona.
- Use both languages on a daily basis.
- Not possible to recruit a group of Catalan “monolinguals” in BCN.

<b>Participants</b>		<b>Mostly S (<i>n</i>=15)</b>	<b>S/C (<i>n</i>=22)</b>	<b>C/S (<i>n</i>=26)</b>	<b>Mostly C (<i>n</i>=19)</b>
<b>Self-reported % Catalan use</b>		<b>11 (8)</b>	<b>40 (7)</b>	<b>63 (6)</b>	<b>86 (8)</b>
<b>Chronological age at test (years)</b>		<b>30 (10)</b>	<b>32 (7)</b>	<b>32 (7)</b>	<b>35 (8)</b>
<b>Years of residence in Barcelona</b>		<b>30 (9)</b>	<b>31 (9)</b>	<b>32 (7)</b>	<b>34 (7)</b>
<b>L1 before schooling (% of participants)</b>	<b>Cat</b>	<b>6.7</b>	<b>0.0</b>	<b>34.6</b>	<b>90.0</b>
	<b>Sp</b>	<b>73.3</b>	<b>76.2</b>	<b>30.8</b>	<b>10.0</b>
	<b>C+S</b>	<b>20.0</b>	<b>23.8</b>	<b>34.6</b>	<b>0.0</b>



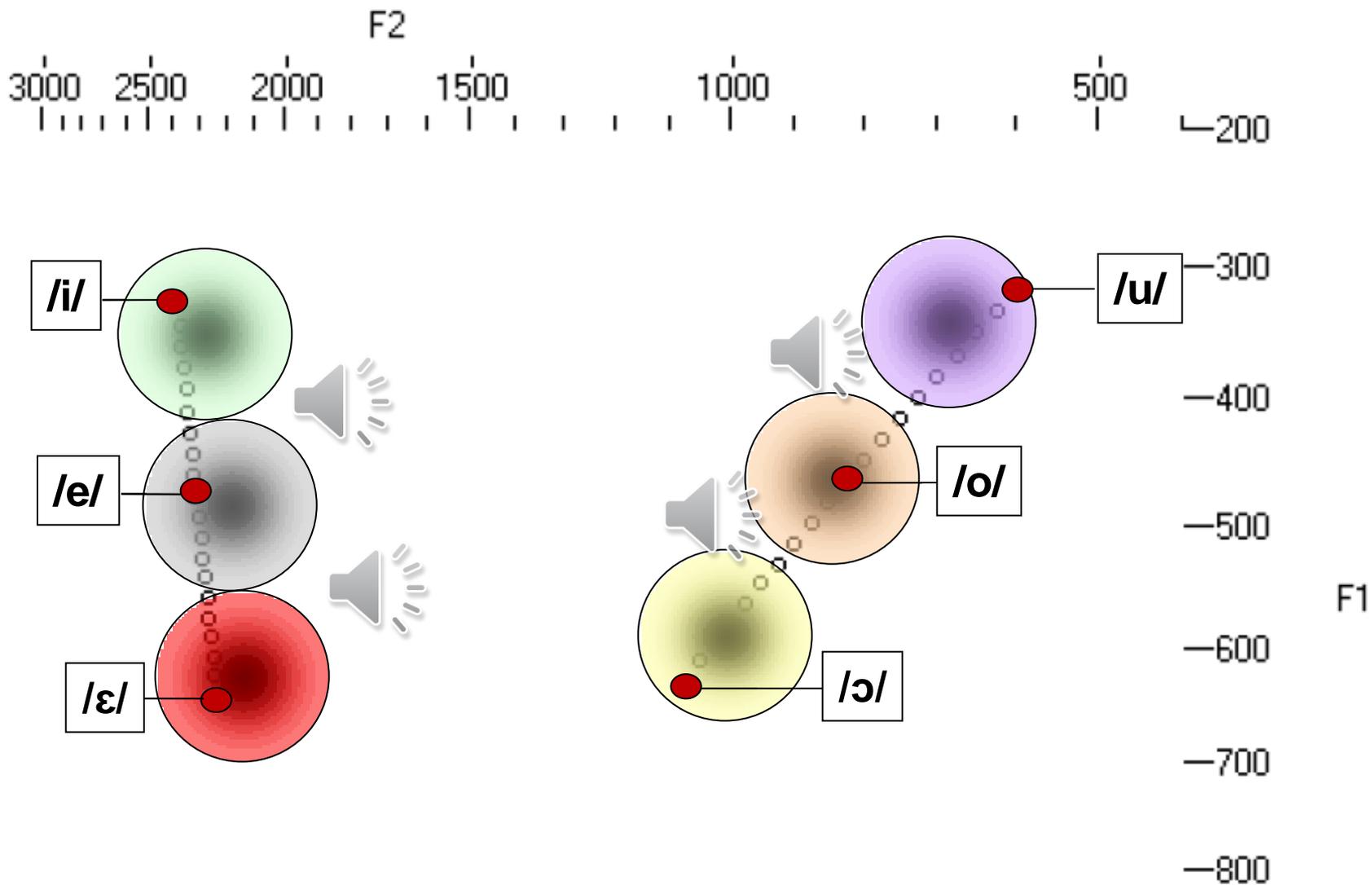
# Method: Perception Tasks

- Identification and Discrimination (AXB) /i-e-ɛ/ and /u-o-ɔ/
- /i-e/ & /u-o/ as control
- Identification x 4 contrasts
  - Front: i → e e → ɛ
  - Back: u → o o → ɔ
- Semi-synthetic stims
- F1 and F2 modified
- 120 trials
  - 10 stimuli
  - 3 repetitions
  - 4 contrasts



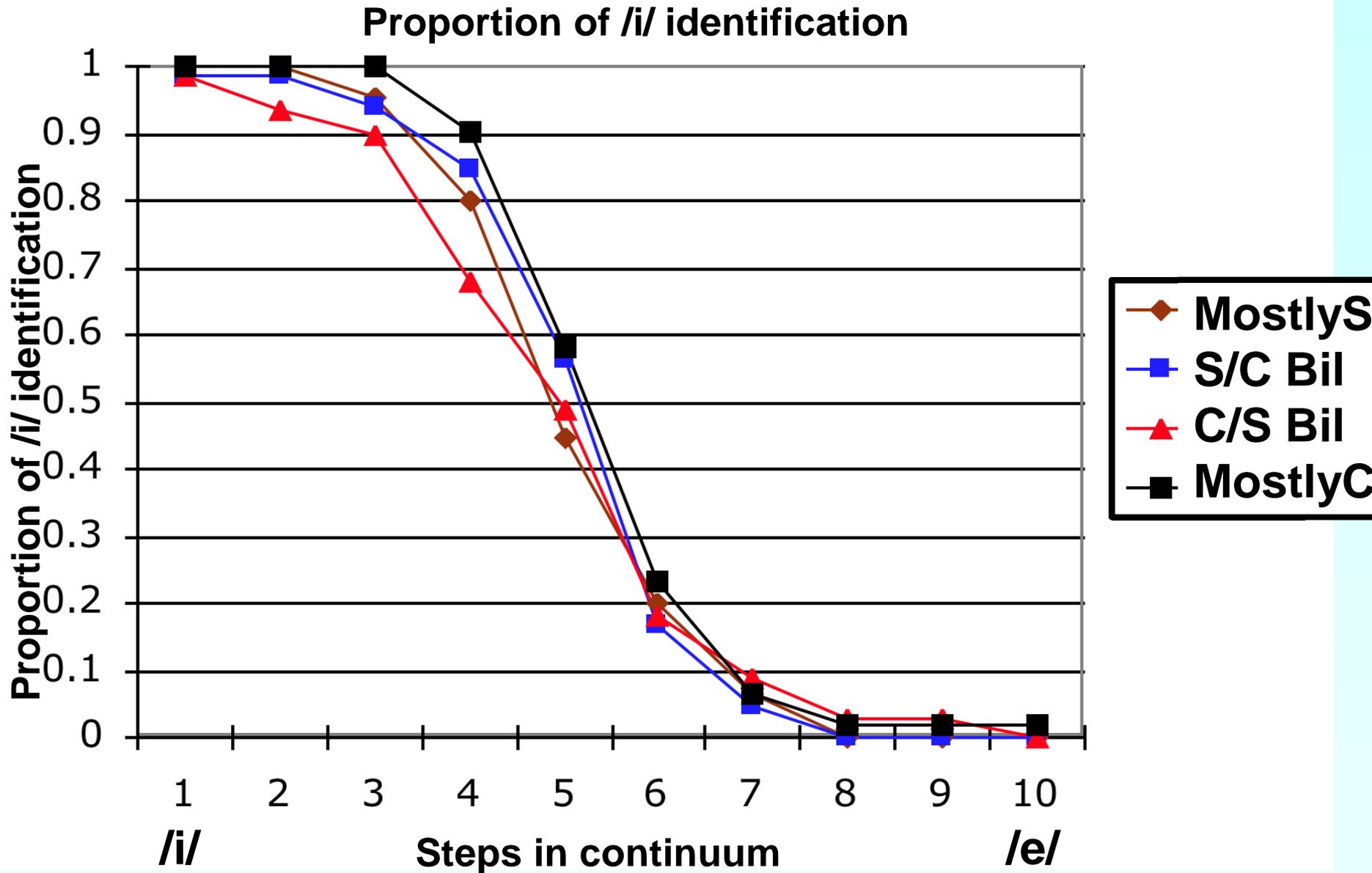


# Method: Perception Tasks





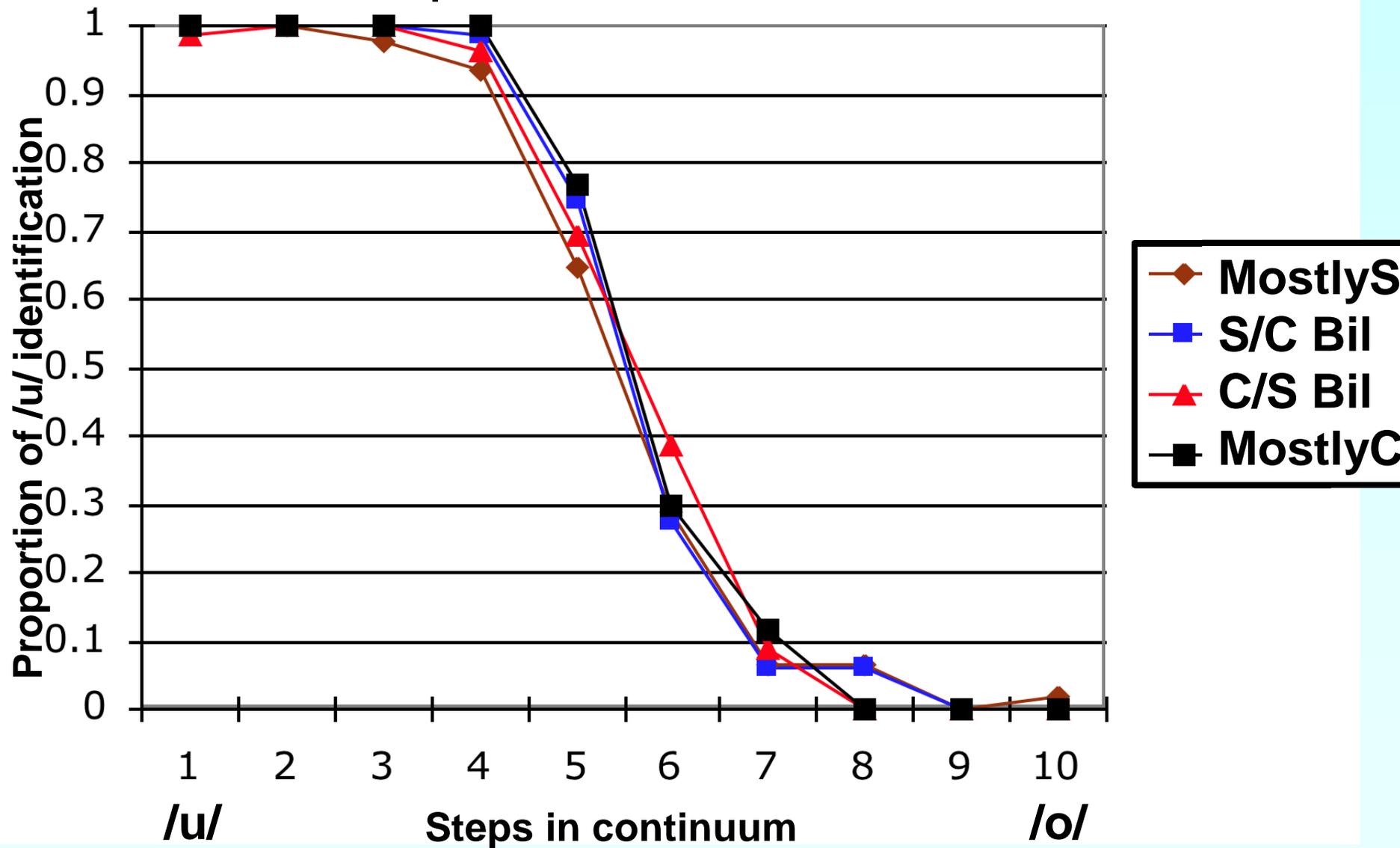
# Results: Front vowels: /i/-/e/





# Results: Back vowels: /u/-/o/

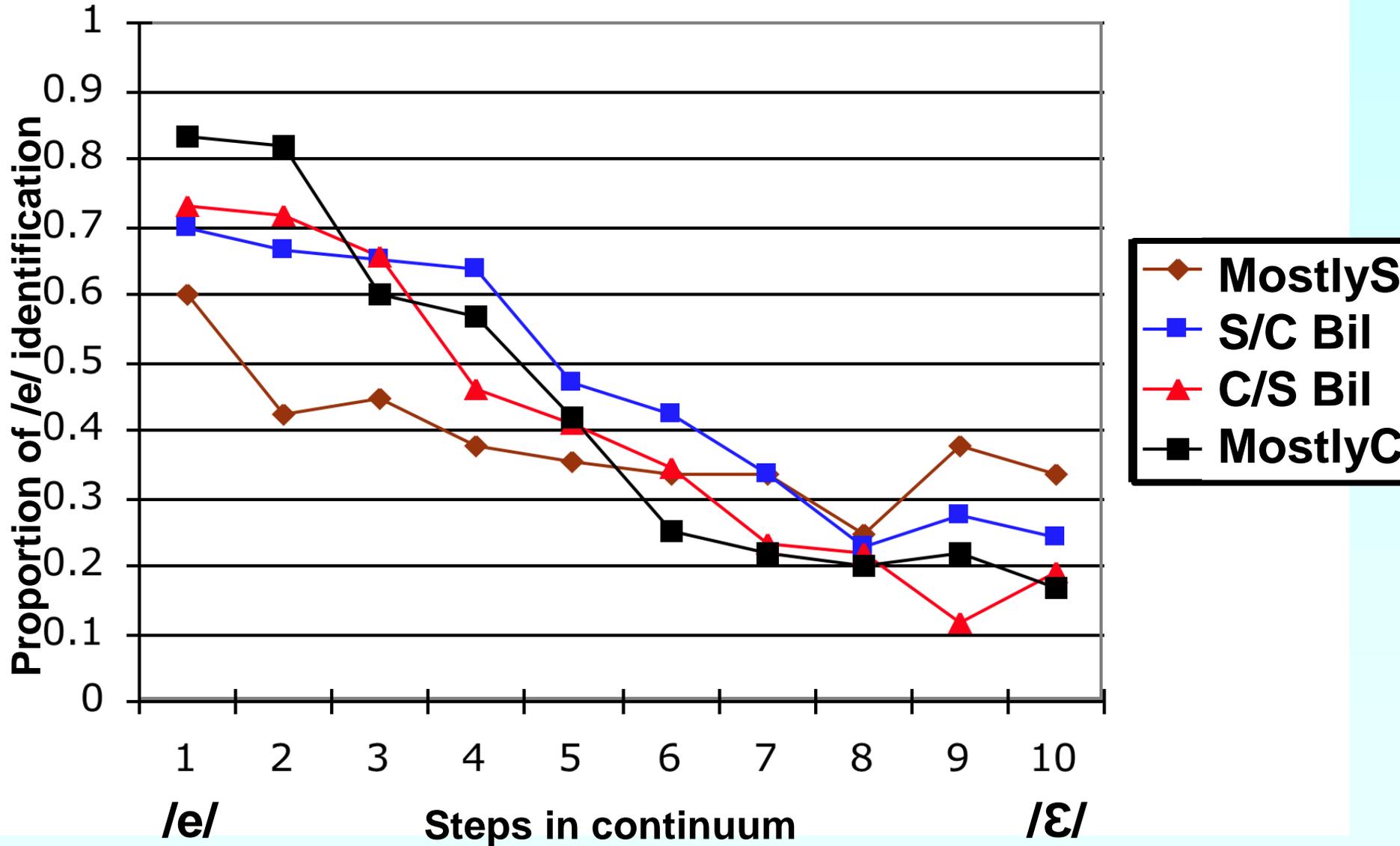
## Proportion of /u/ identification





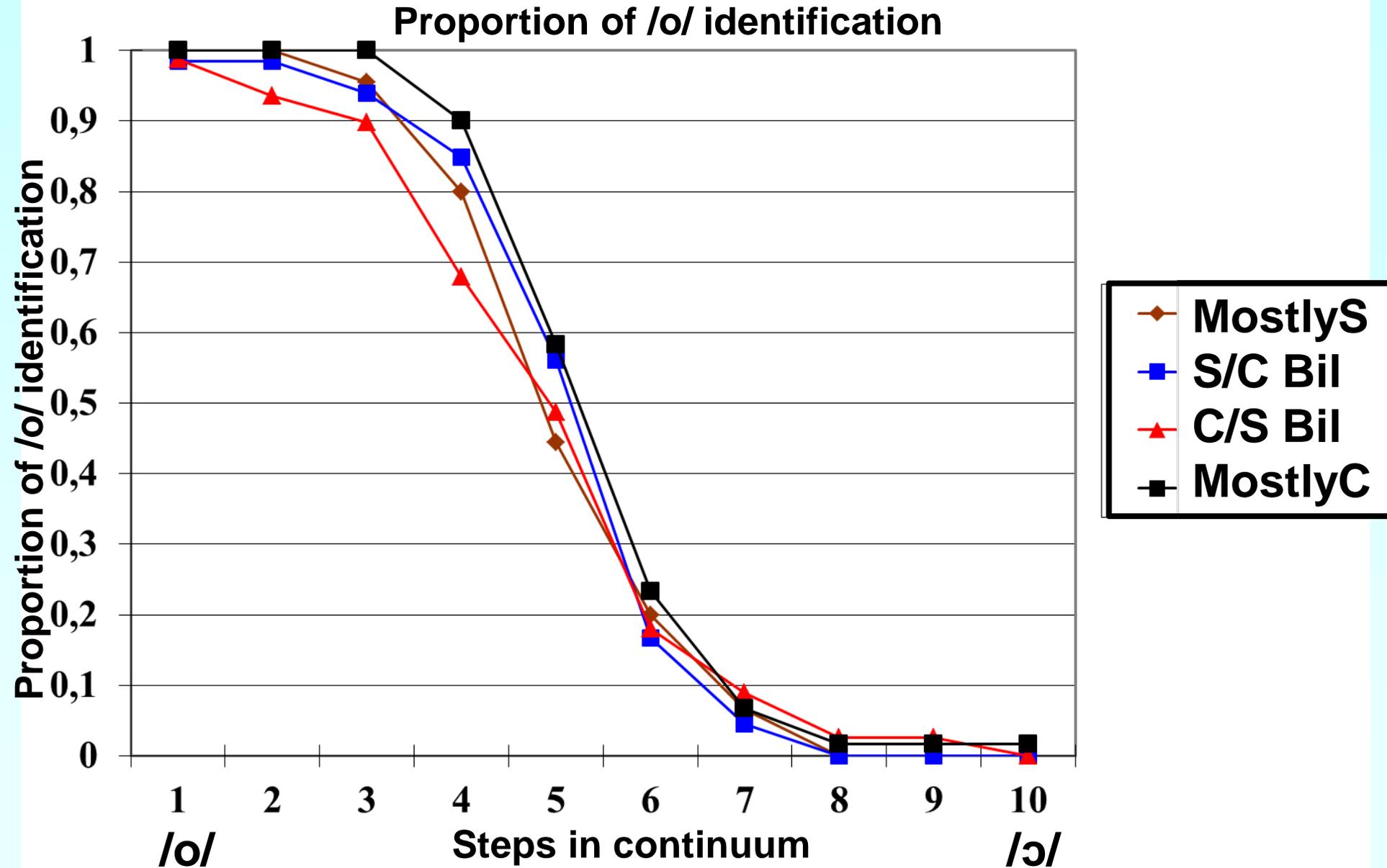
# Results: Front vowels: /e/-/ɛ/

## Proportion of /e/ identification





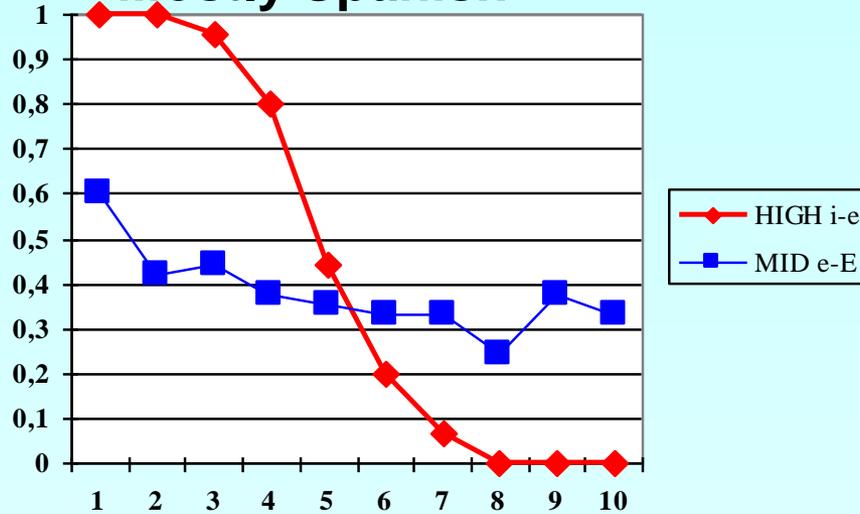
# Back vowels: /o/-/ɔ/. Identification



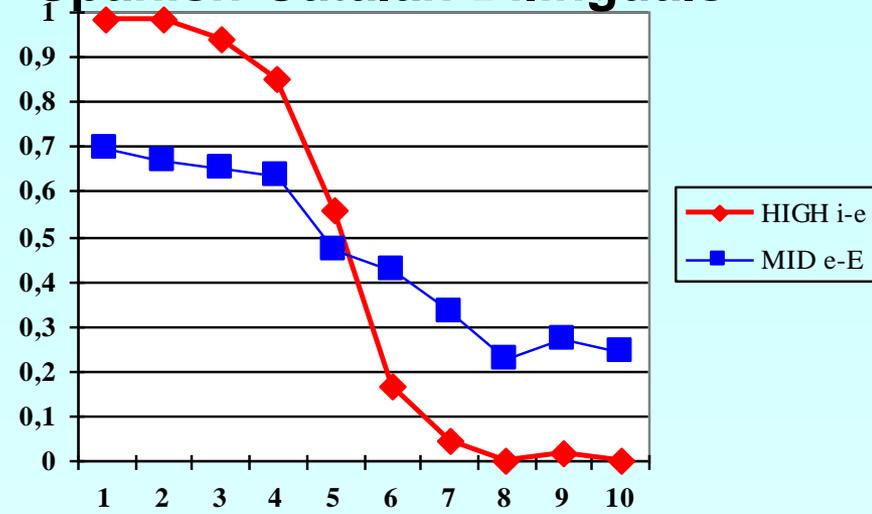


# Results: Front vowels: /i/-/e/ vs. /e/-/ɛ/. Identification

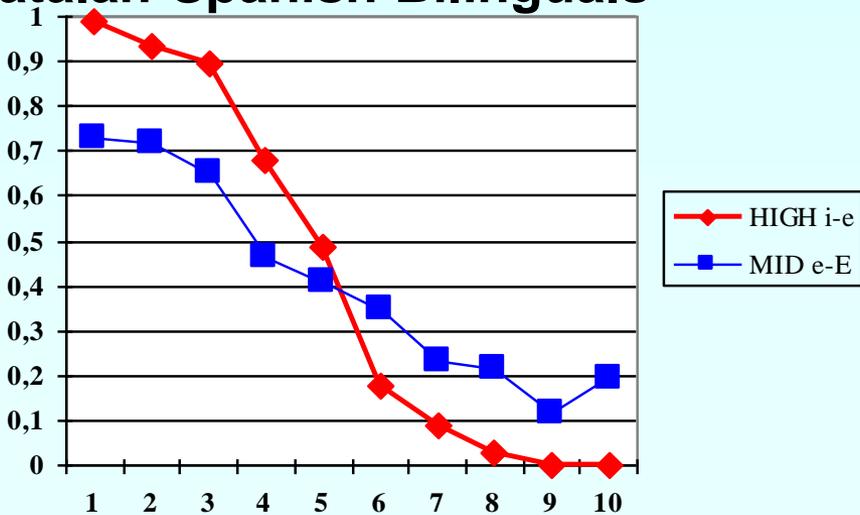
## Mostly Spanish



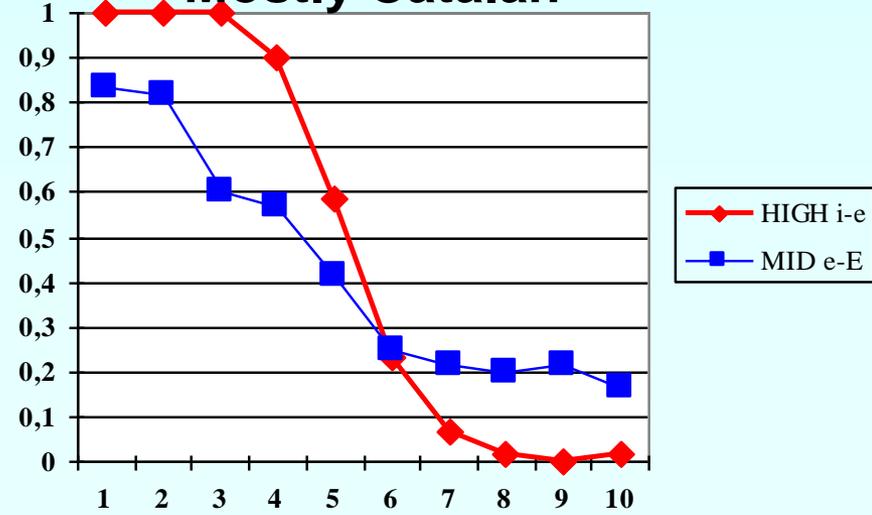
## Spanish-Catalan Bilinguals



## Catalan-Spanish Bilinguals

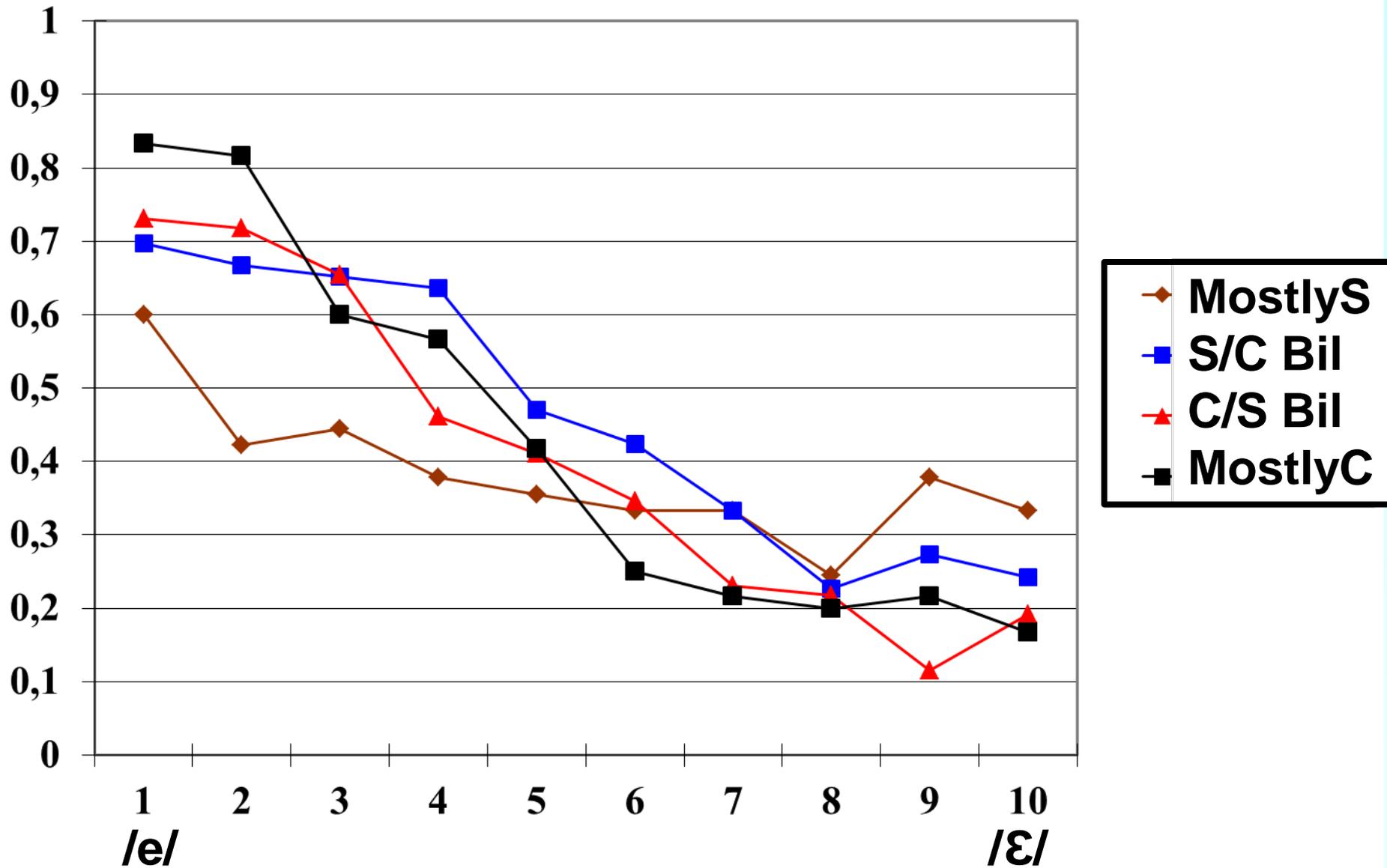


## Mostly Catalan



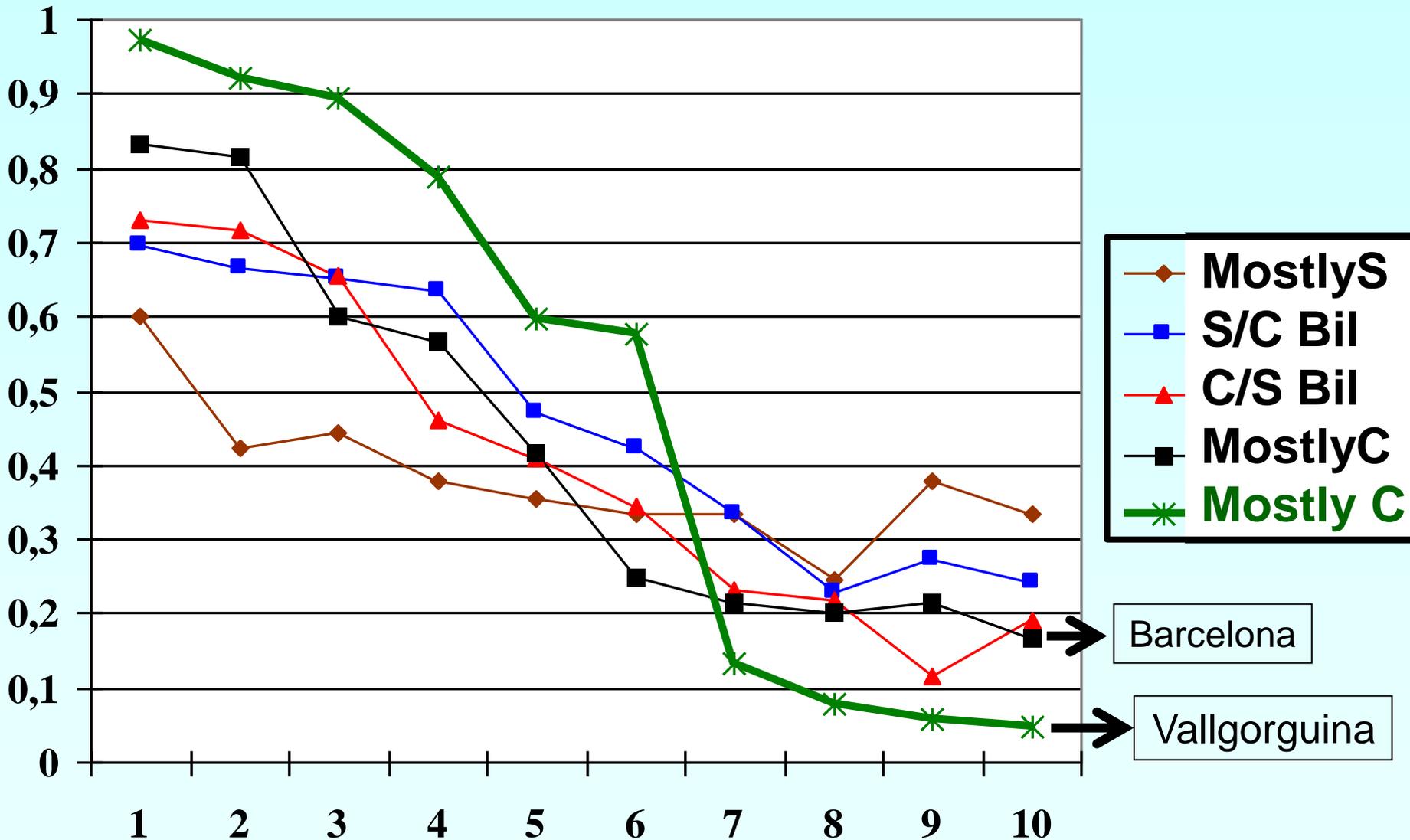


# Front vowels: /e/-/ɛ/. Identification



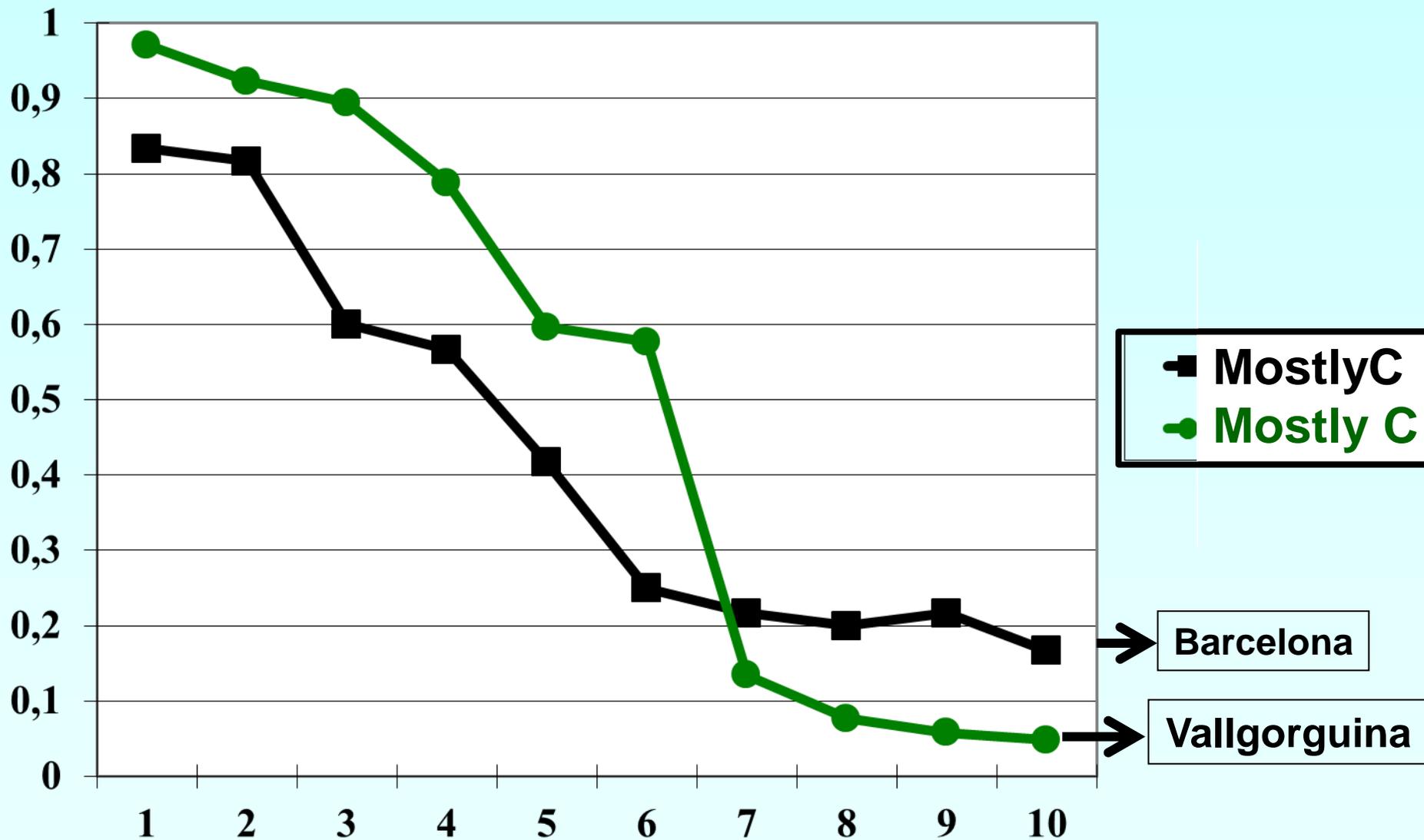


# Front vowels: /e/-/ɛ/. Identification





# Front vowels: /e/-/ɛ/. Identification





# Study 1: production

## Reading aloud (for meaning) a passage in Catalan

[ənz əs'tan prə'nen əl 'pɛl / i no ez 'zɯst // əs 'pɛnsən kə som 'seks / i 'muts / i əs'tupits //  
 um 'pis də sə'ɣonə 'ma ðə 'mɛɲz də 'trɛntə 'mɛtrəs kwə'ðrats / ez unə 'kɔzə kə nin'gu no  
 'βɔl // prɔ ʒɔ no ez um 'fet in'sɔlit // 'ʒa 'fa 'temps kə lə 'ʒen no 'sap kɛ 'fe pər əksə'di ə  
 un 'pis də'sen / pərke no su 'pɔt pər'mɛtrə // ən əspə'sjal pər'sonəz əmb un 'sɔw 'βaf i se  
 nsə pu'ðɛr əku'nɔmik / kɔm pər əg'zemplə 'ʒen 'ʒoβə // prɔ nin'gu no əs 'keʃə // əl pru'βl  
 ɛmə es kə / sə'ɣonz lə 'ʎej / əkɛts 'pizuz no əs 'pɔðəm 'bɛndrə // pər ə'ʃɔ əl rəʒi'ðo 'ʒɔrði  
 mɛstrəz βa 'ði kə 'kal mes kunt'rɔl / pərke no ni a 'prɔw / i sau'riə də tən'ka 'mes l ə'ʃɛtə  
 dəlz bənə'fisis d əl'ɣuns // əl kə 's a ðə 'fe es pu'za unə 'multə ə ə'kɛʎz prupjə'taris kə ə  
 m 'totə lə 'malə 'fɛ 'pɔzin ə lə 'βɛndə um 'pis sensə kə ə'kɛt kum'plɛʃi ləz 'miniməs ku  
 ndi'sions pər 'viwrə i 'be]

### selection of words (stressed vowels only)

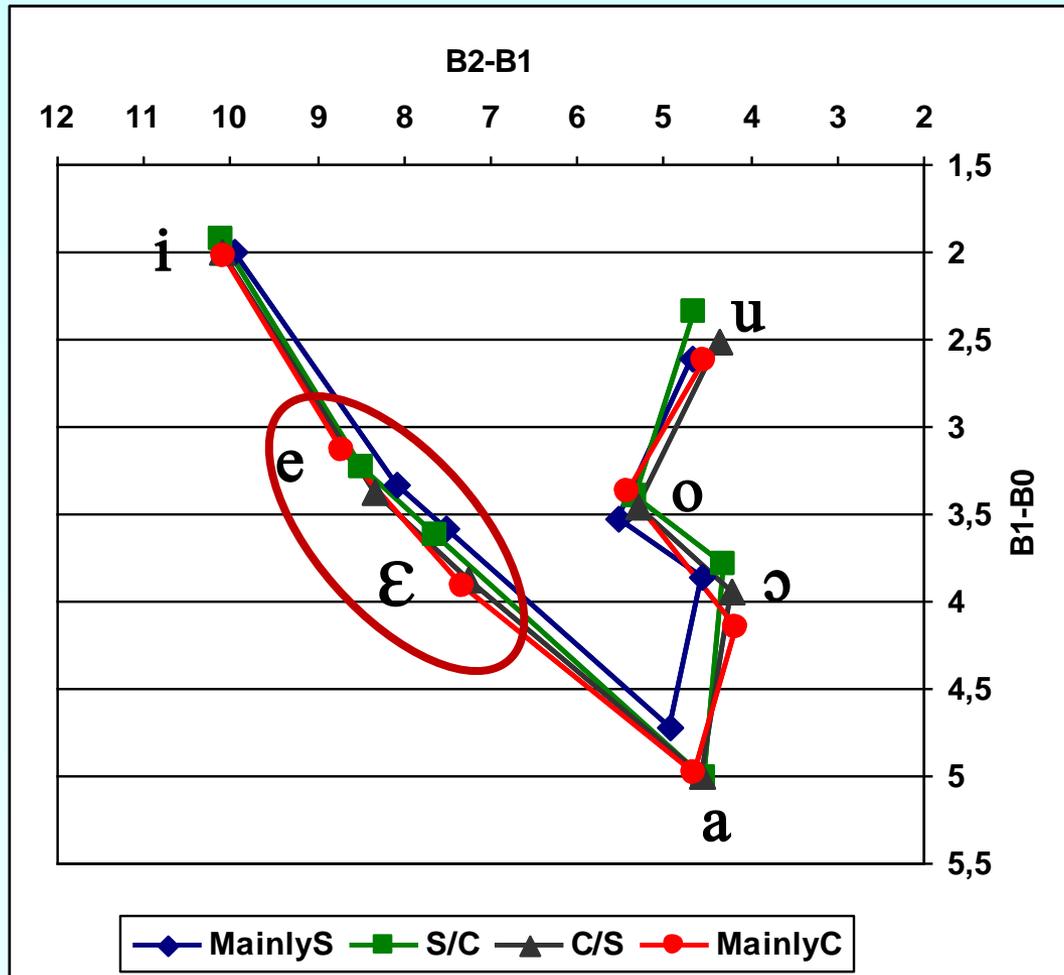
Vowels →	i	e	ɛ	a	ɔ	o	u
Tokens x Speaker →	5	8	8	5	8	8	5



# Results: production

## Vowel quality measures

- Normalized for gender and oral tract size differences
- Spectral distance score

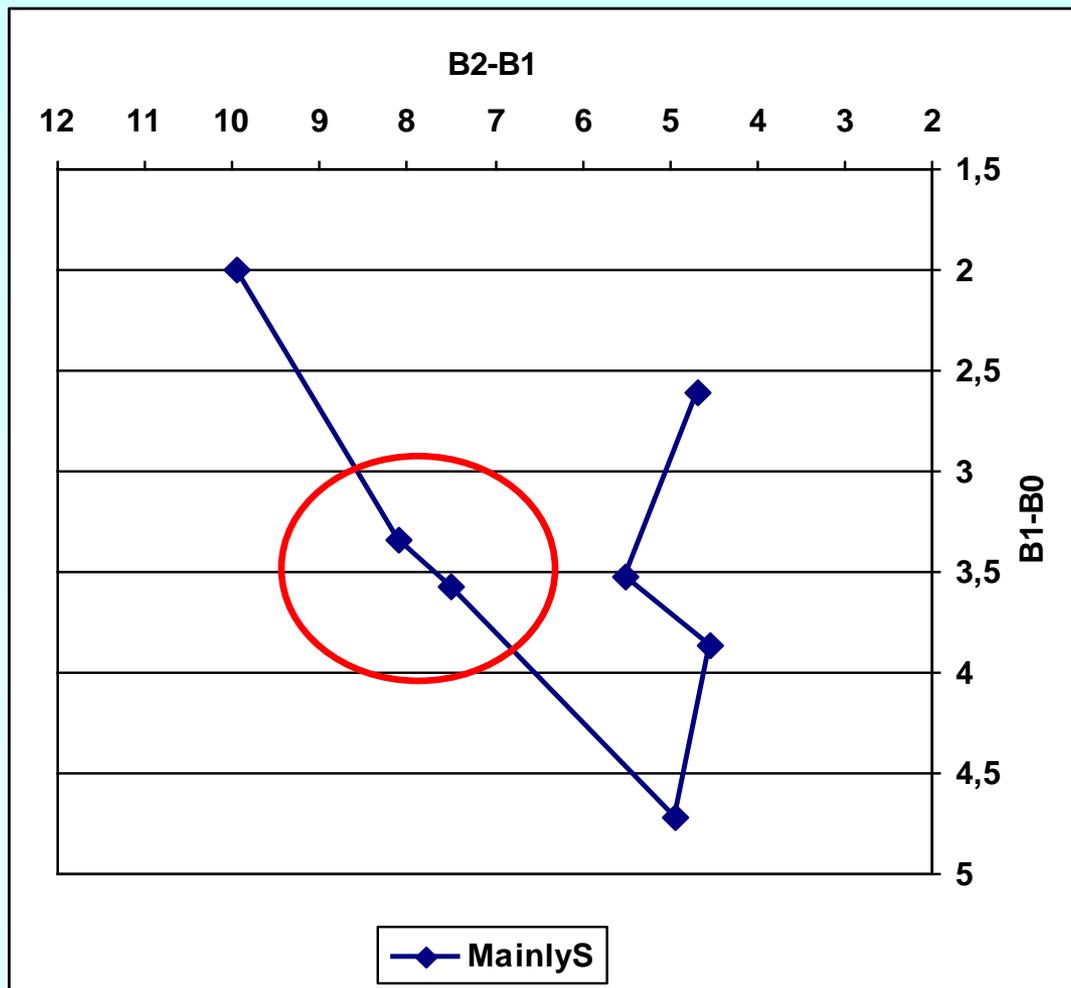




# Results: production

## Vowel quality measures

Bilinguals that mainly spoke Spanish (11% Catalan Use) produced a small spectral distance between contrasting vowels.

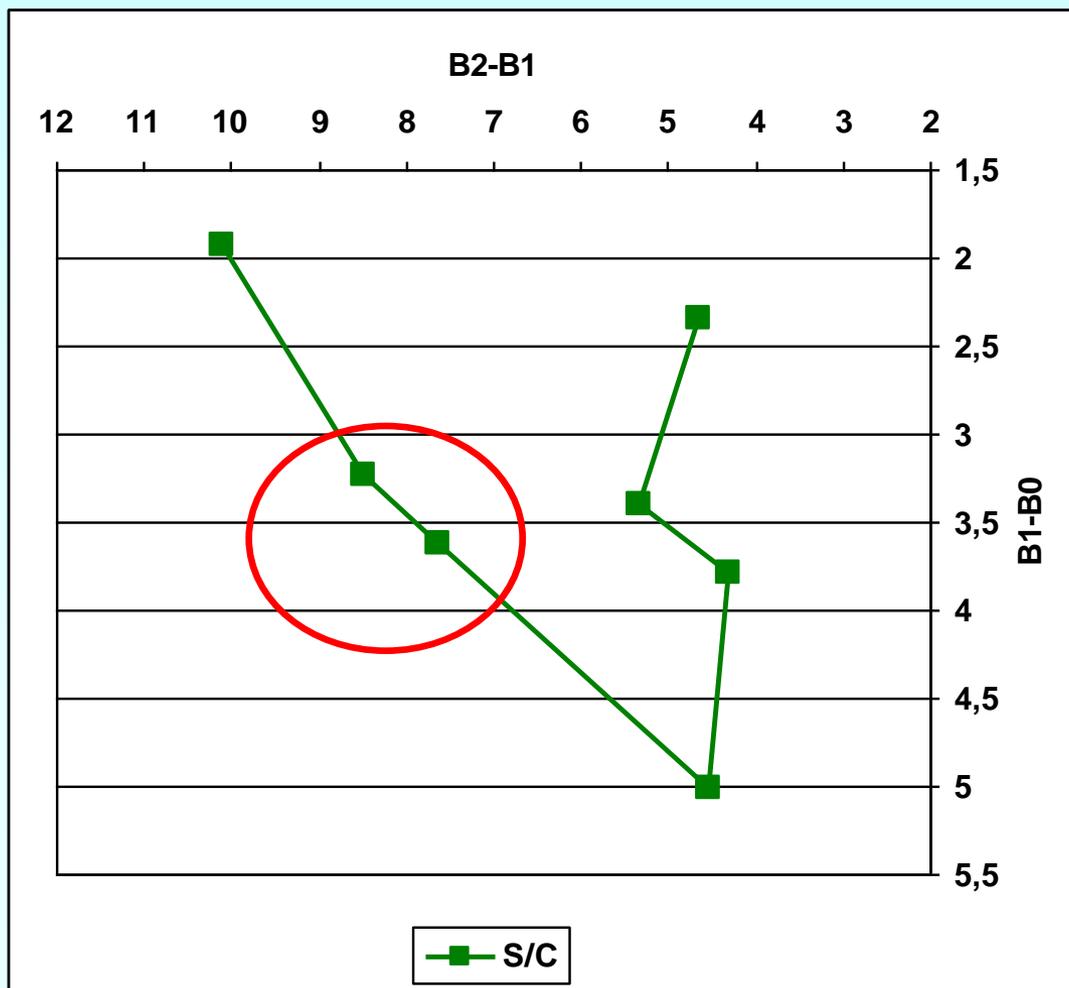




# Results: production

## Vowel quality measures

Spanish-Catalan bilinguals reporting 40% of Catalan Use

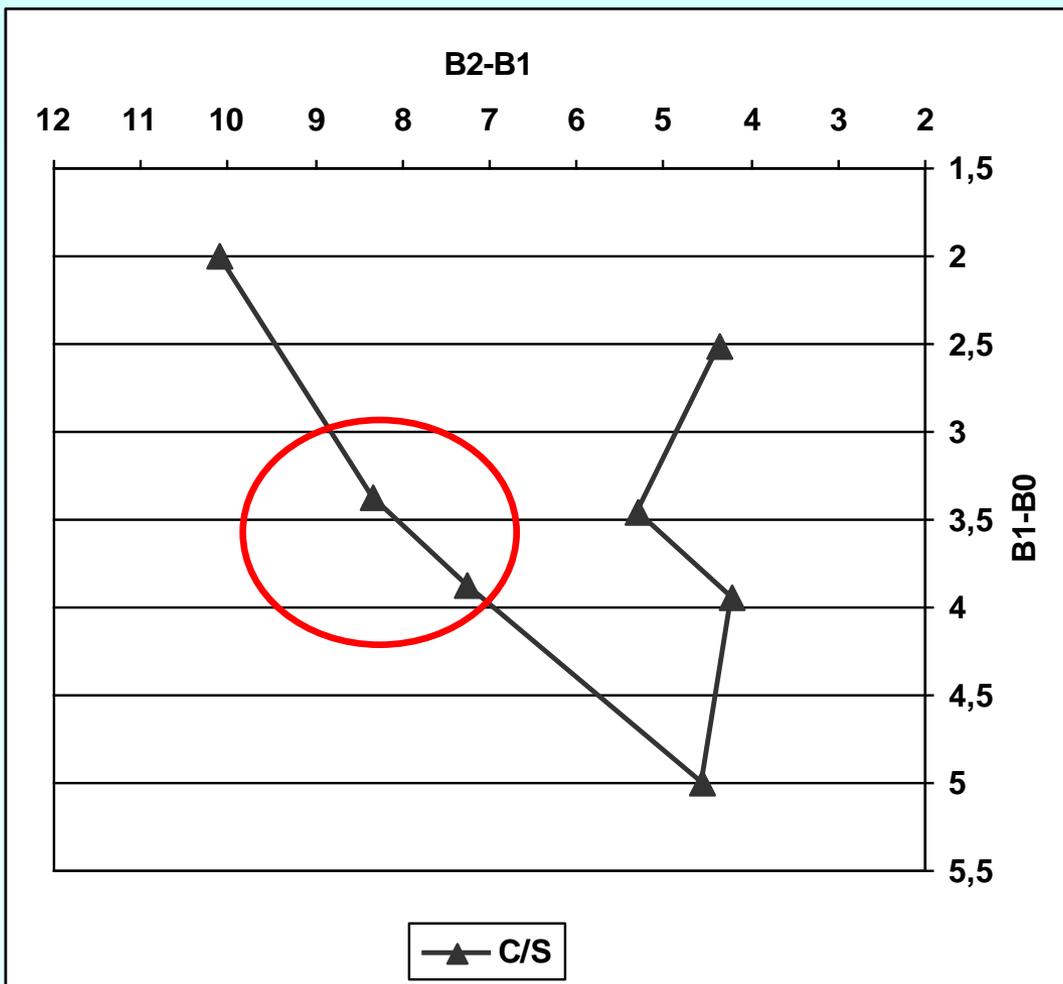




# Results: production

## Vowel quality measures

- Catalan-Spanish bilinguals reporting 63% of Catalan Use

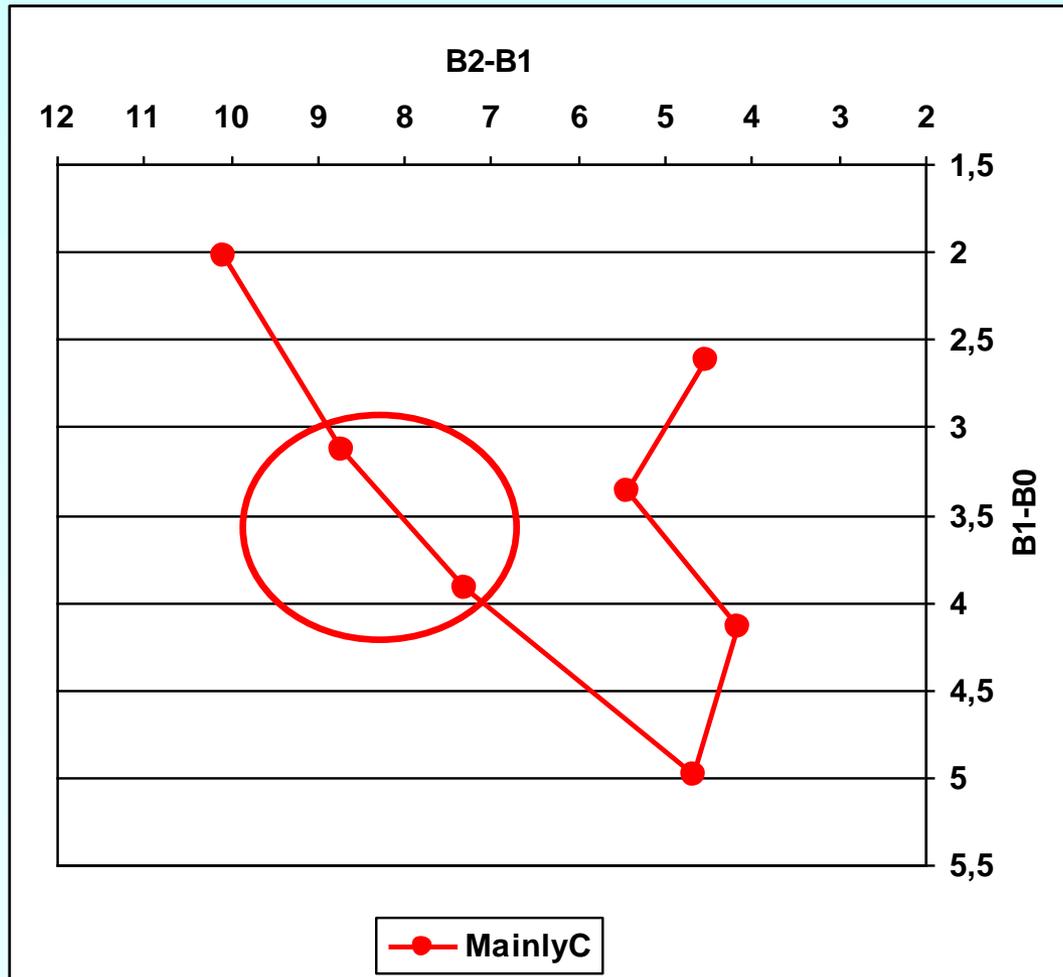




# Results: production

## Vowel quality measures

Bilinguals that mainly spoke Catalan (83% Catalan Use) produced the largest spectral distance between contrasting vowels.



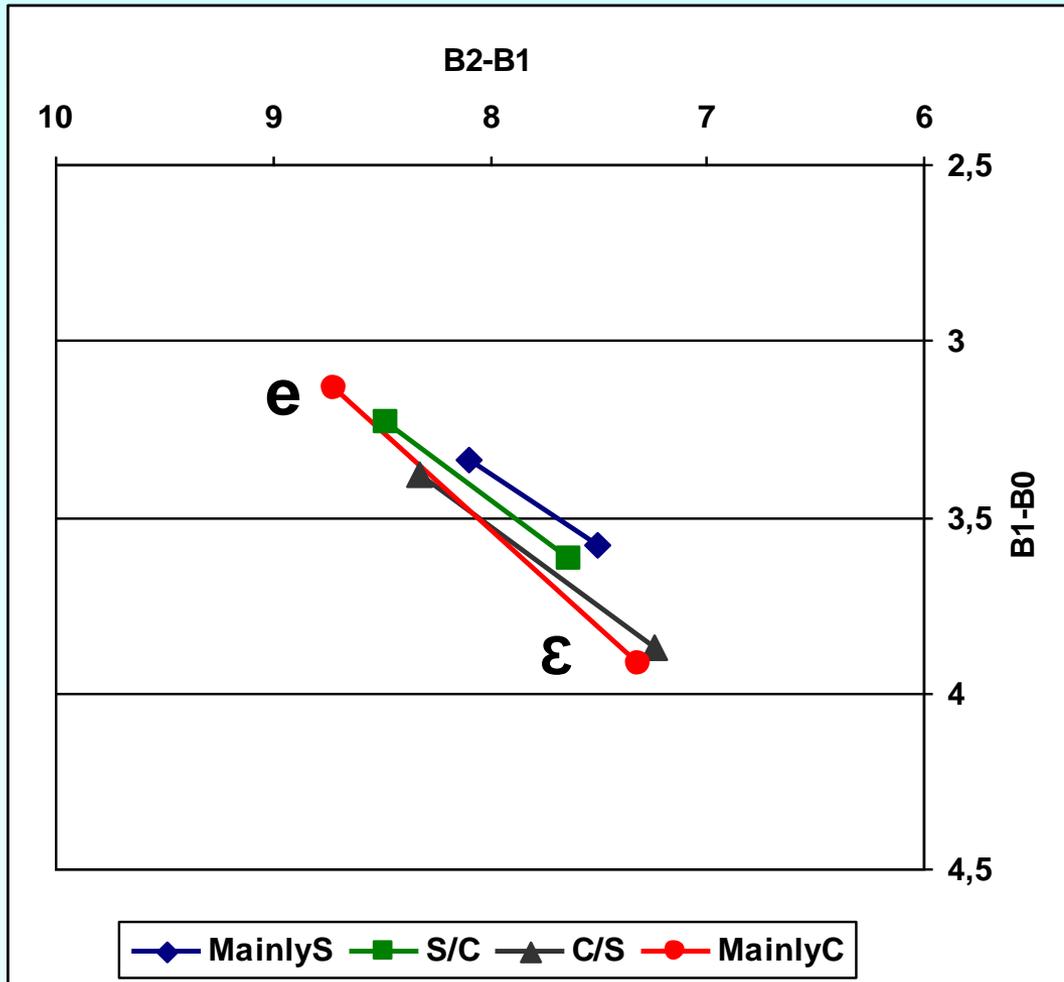


# Results: production

ANOVA on spectral distance measures

within Ss = Vowel Contrast (/i/-e/, /u/-o/, /e/-ε/, /o/-ɔ/)

between Ss = Subject Group (Mainly S, S/C B, C/S B, Mainly C)

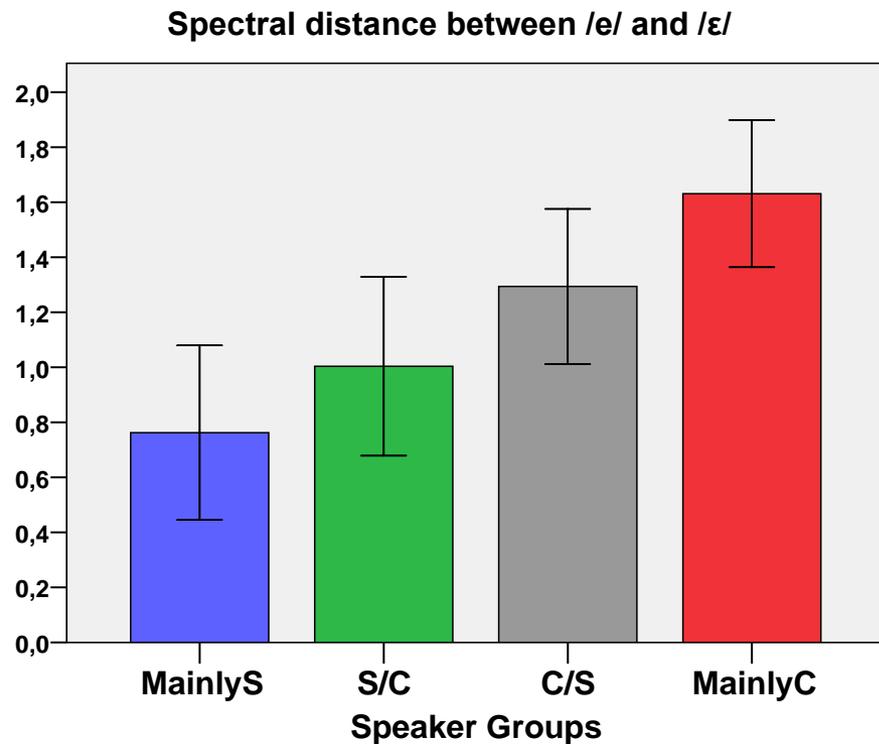
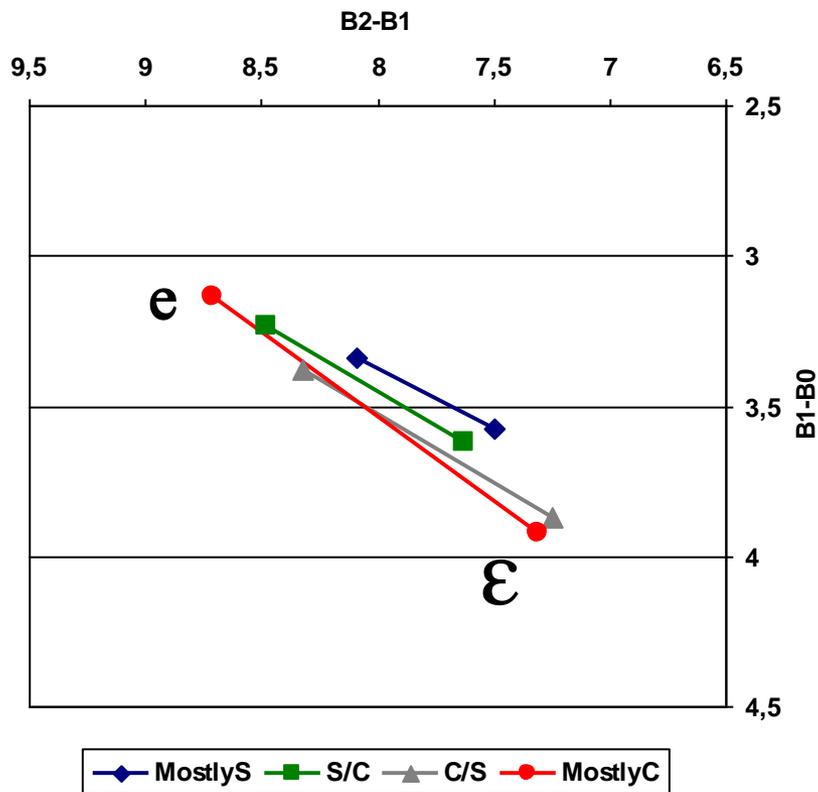


- **Sig.** main effect of *Vowel Contrast* ( $p < .001$ )
- n.s. main effect of *Subject Group* ( $p > .05$ )
- **Sig.** *Vowel Contrast* x *Subject Group* interaction ( $p < .001$ )

**/e/-ε/ distance varied as a function of subject group.**



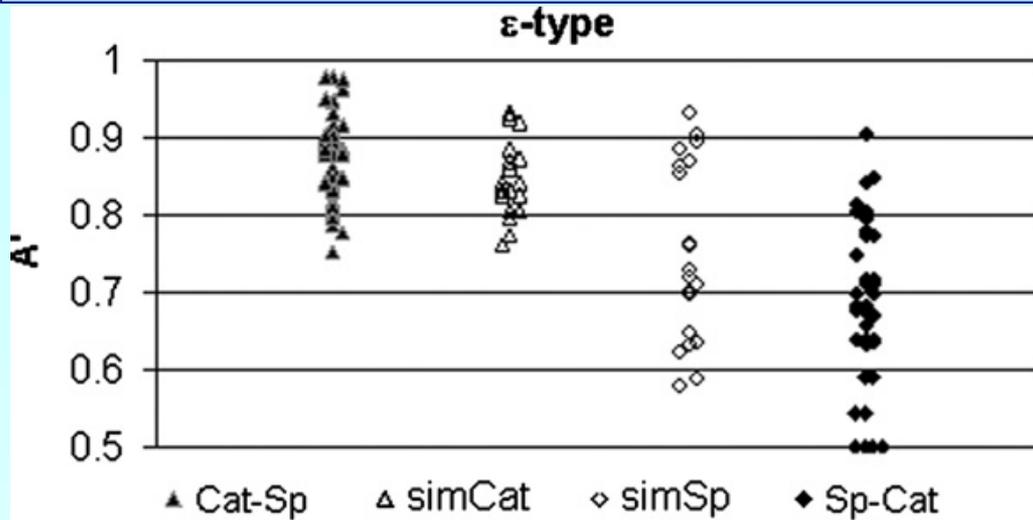
# Results: production



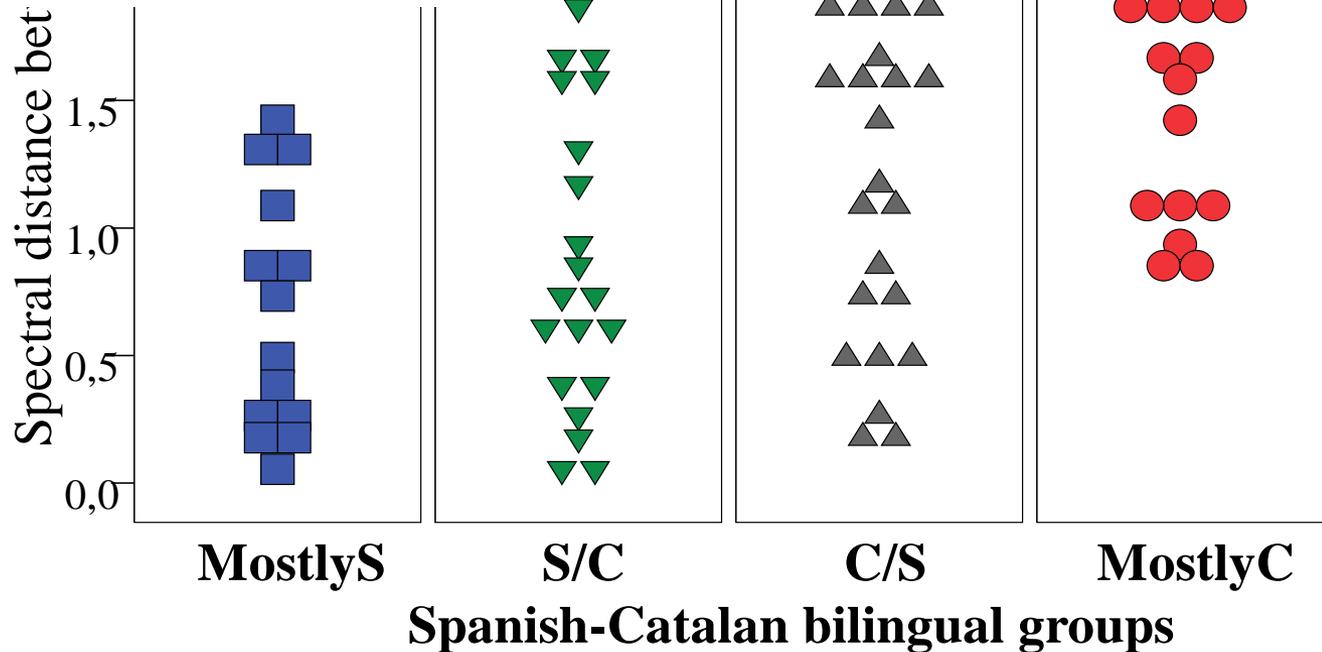
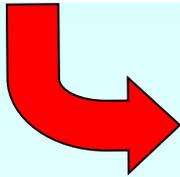
How well do these mean spectral distance scores reflect **individual data**?



# Results: production



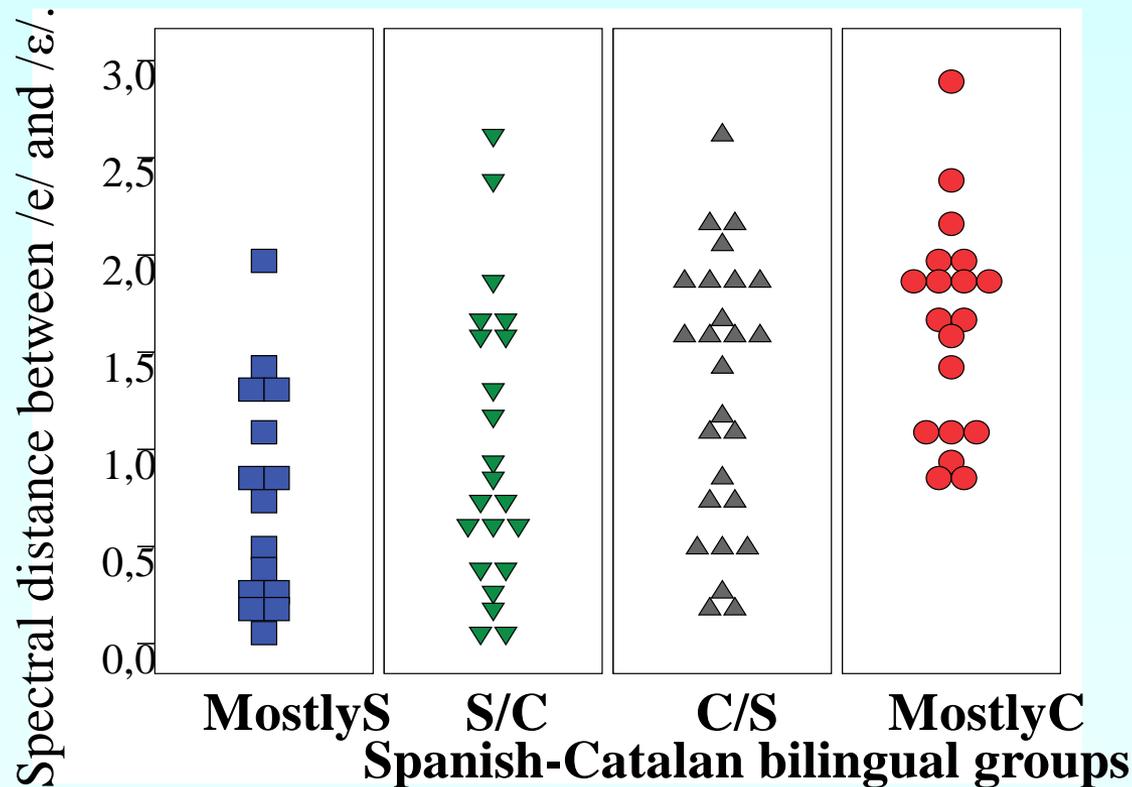
ion in production.





## Results: production

The proportion of bilinguals who perceive the /e/-/ɛ/ contrast categorically and produce it with a distinct spectral difference is larger ( $p=.009$ ) in those participant groups that used Catalan more frequently.





## Conclusions Study 1

Categorical perception of /e/-/ɛ/

- > two distinct phonetic categories for /e/ and /ɛ/?
- > realized these vowels more distinctly

Non-categorical perception of /e/-/ɛ/

- > non-distinct phonetic categories for /e/-/ɛ/?
- > realized these vowels less distinctly.

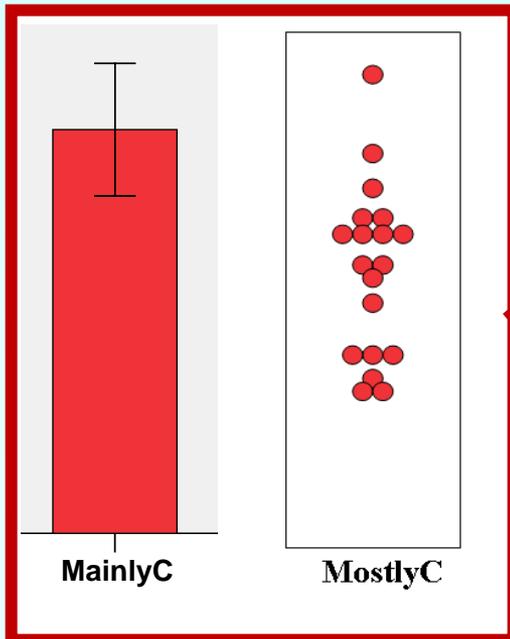
**Catalan /e/-/ɛ/ is less robust than /i/-/e/. Spanish-Catalan bilinguals may find it more difficult to form accurate categories for these vowels than for other vowels of Catalan.**

**Variations in L1/L2 use/experience may affect the performance of bilingual adults in the perception and production of the Catalan mid vowel contrasts.**

## Study 2: One mid vowel contrast: /e/-/ɛ/.

### Participants (adult Catalan-dominant C/S bilinguals)

- **N= 43** (interview/questionnaire)
- Native Catalan-speaking parents (BCN & Borredà)
- Identification + Discrimination (AXB) tasks based on a lexical /fe/-/fɛ/ continuum.
- Isolated words **MPs / Cognates / Non-Cognates**



	Age			% Cat Use		
	Mean	SD	Range	Mean	SD	Range
	32.21	9.89	20-49	<b>62.14</b>	10.32	<b>40-70</b>
	28.53	7.41	18-43	<b>87.67</b>	4.95	<b>80-95</b>
	29.19	9.57	17-52	<b>95.36</b>	5.36	<b>85-100</b>

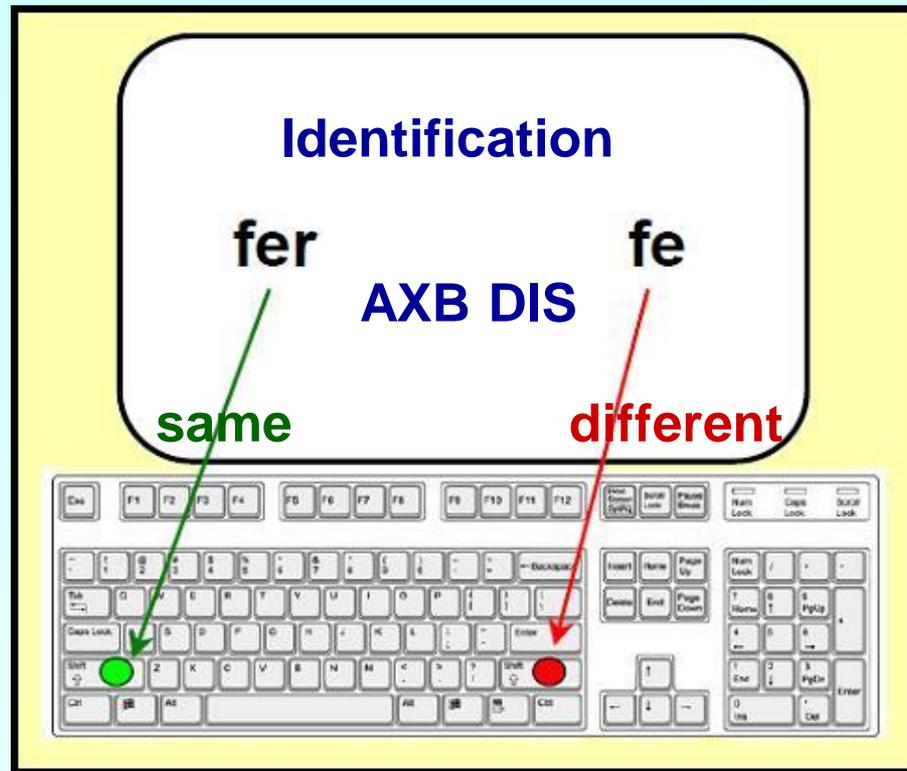
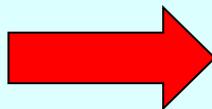
Can this type of variation be explained through individual patterns of L1 (Catalan) and L2 (Spanish) use?



# Study 2: Perception

*fer* /fe/ “to do” vs. *fe* /fɛ/ “faith”

	F1	F2
1	426	2069
2	449	2046
3	472	2024
4	497	2002
5	520	1979
6	544	1957
7	567	1935
8	591	1912
9	613	1890
10	638	1868



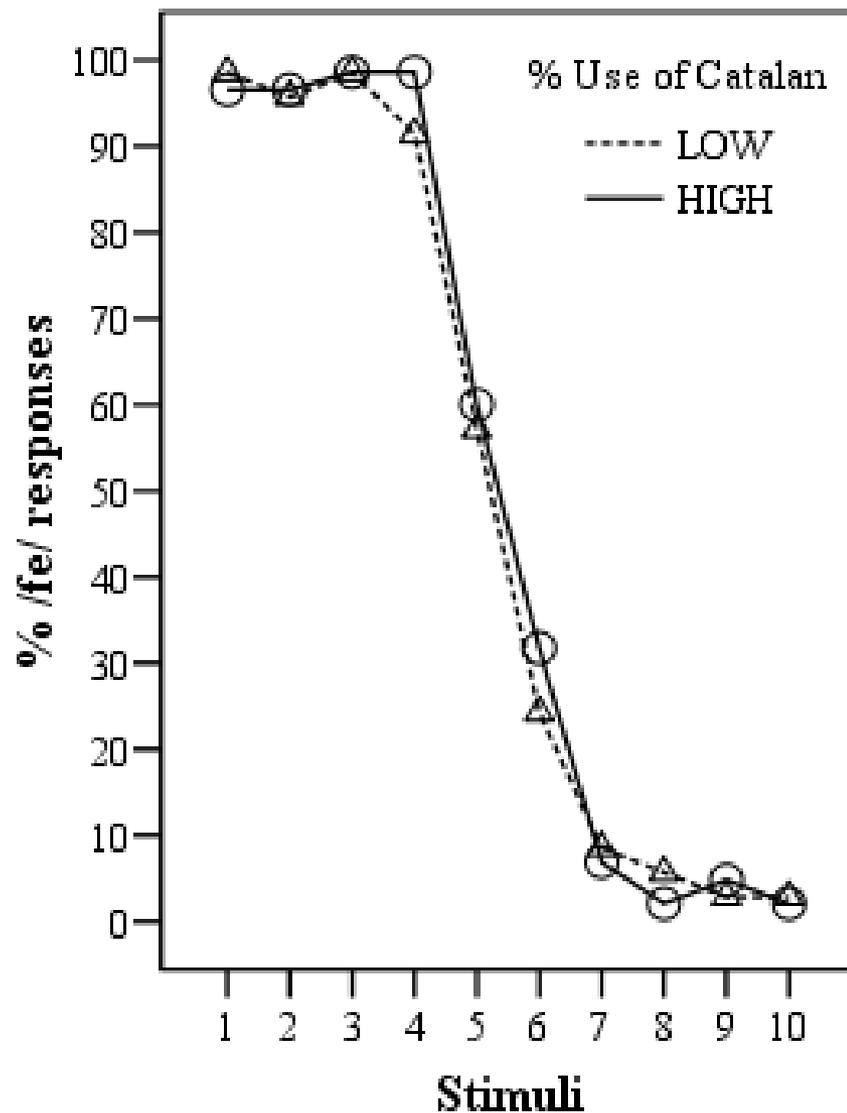
**AXB Discrimination**

<b>A</b>	<b>X</b>	<b>B</b>
<b>/fe/</b>	<b>?</b>	<b>/fɛ/</b>

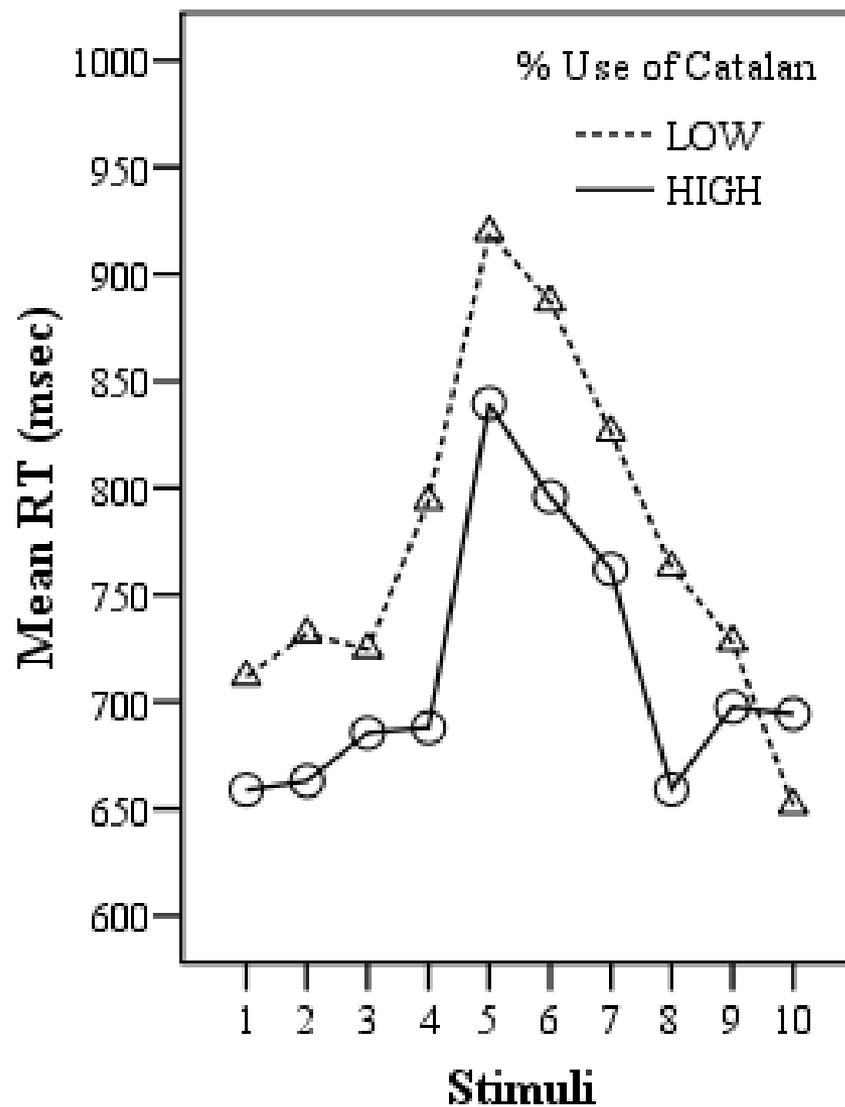


## Study 2: Perception. Results

### /fe/-/fɛ/ Identification Function



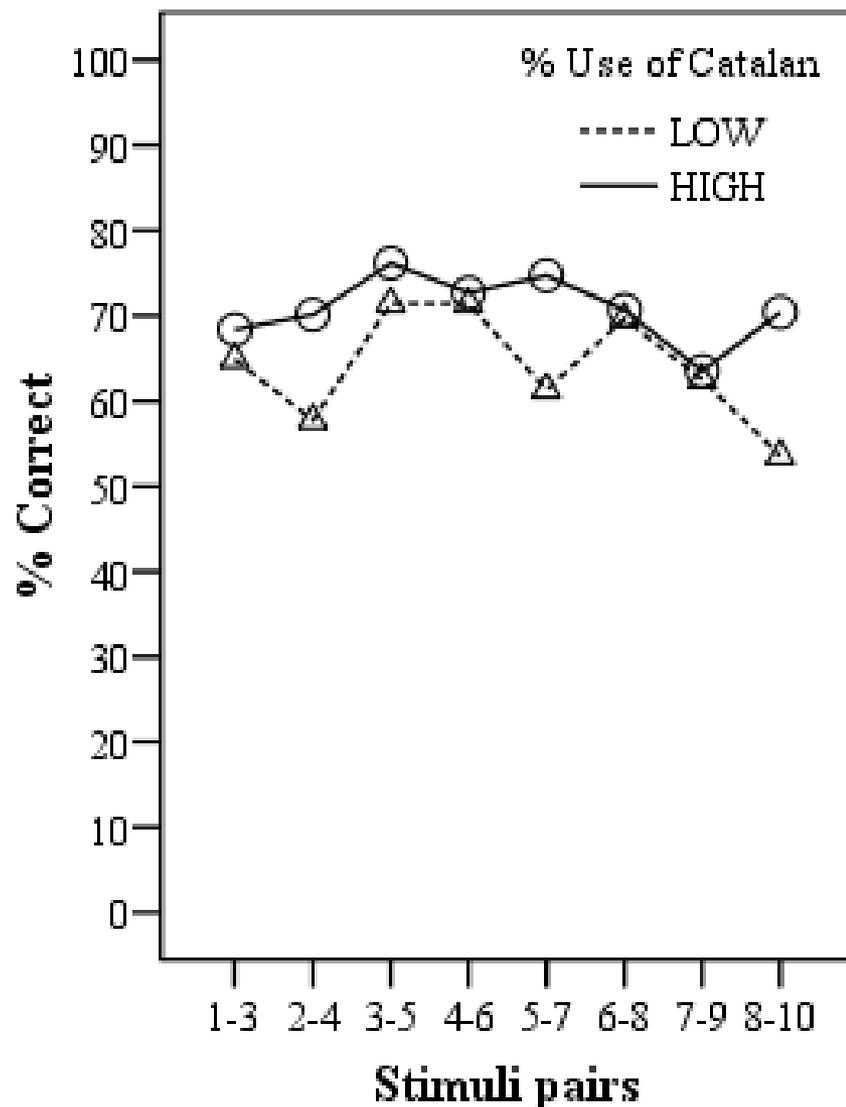
### Identification RTs



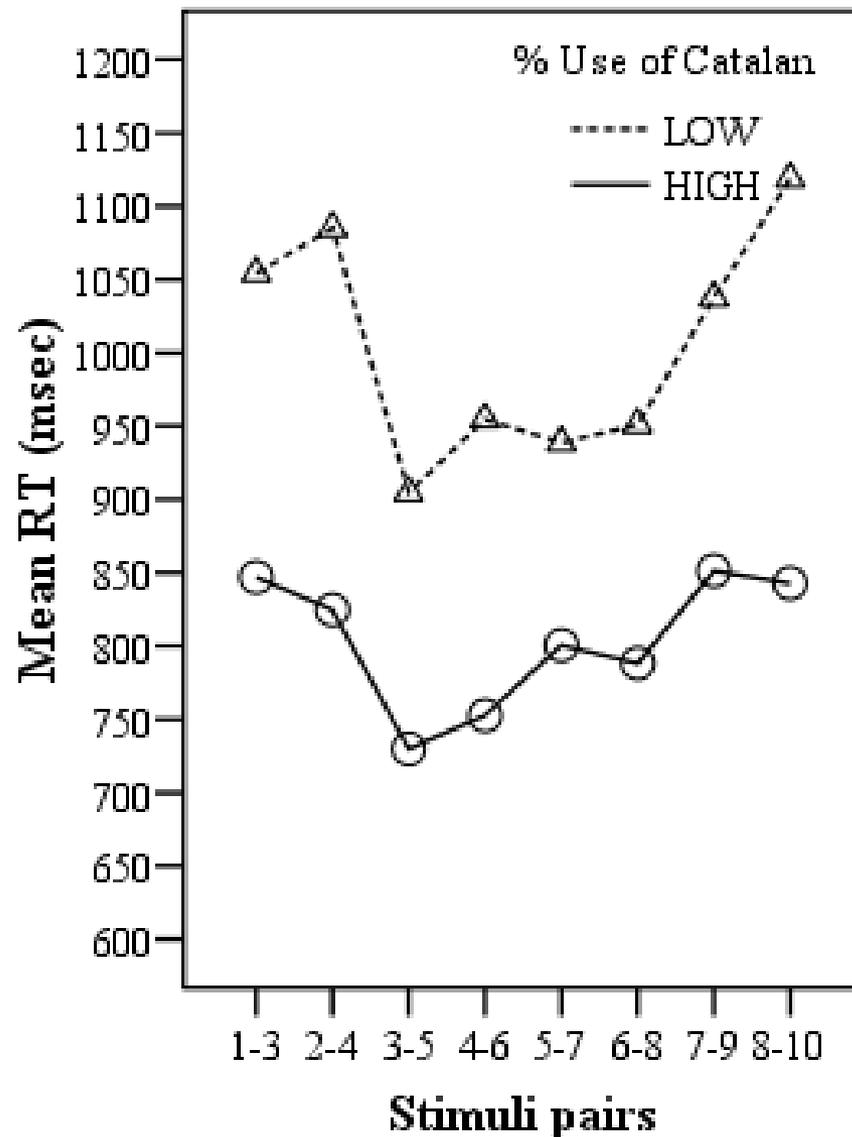


## Study 2: Perception. Results

### AXB Discrimination



### Discrimination RTs





## Study 2: Perception. Results

- **HIGH** Cat use bilinguals discriminated the contrast
  - more accurately
  - significantly faster
- Amount of L1/L2 use does not produce changes at the level of categorical perception, **BUT** results suggest:
- Amount of L1 use affects efficiency of the perceptual system in the processing of L1 sounds
  - > L2 experience affects L1 perception.



## Study 2: Production.

Elicited several repetitions of words in isolation

### 10 Minimal pairs

cec /sɛk/ “blind” vs. sec /sɛk/ “I sit”

### 21 Cognates

maleta /məlɛtə/ vs. Sp. maleta /malɛta/  
“suitcase”

### 21 Non-Cognates

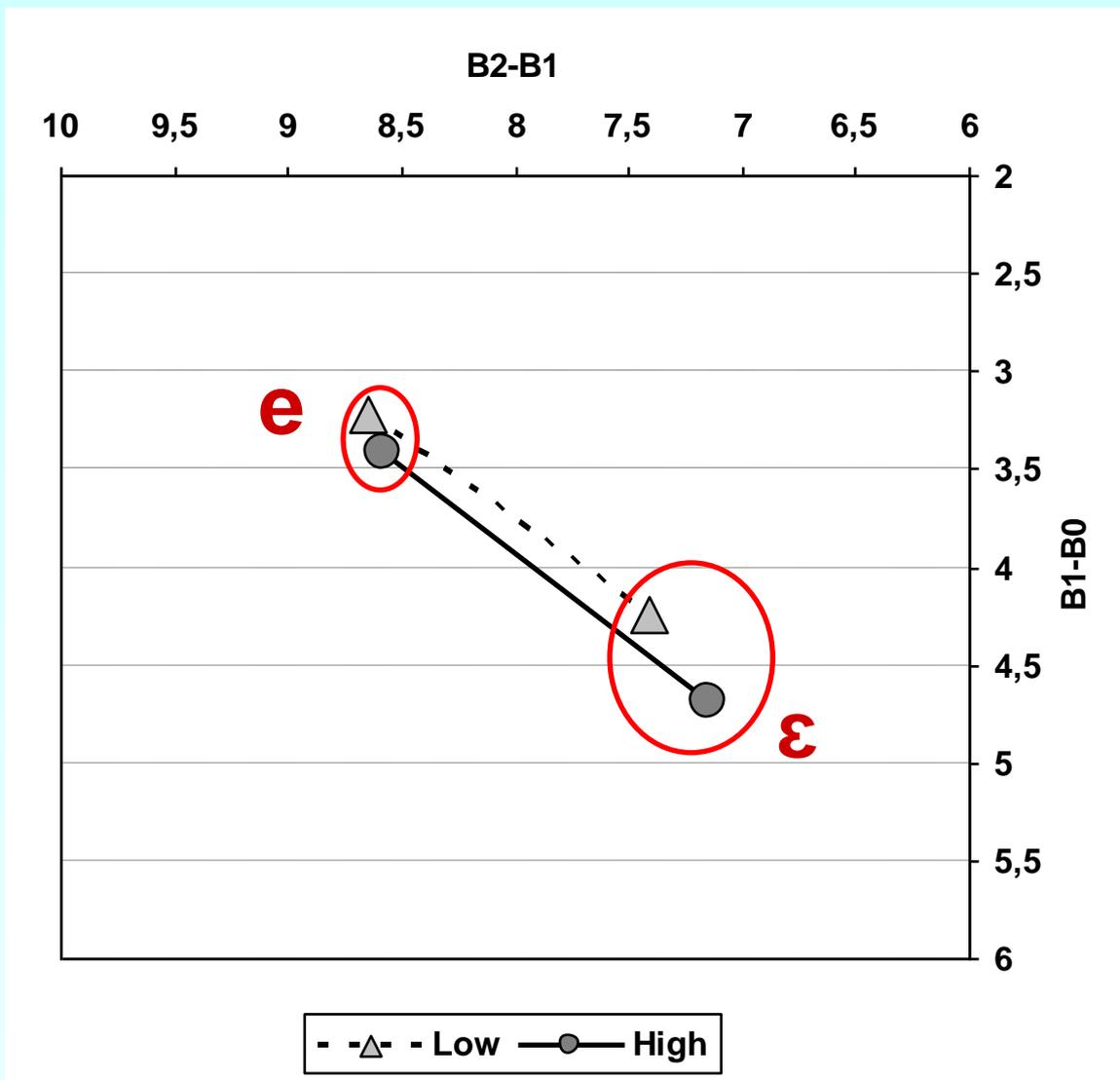
bolet /bulɛt/ vs. Sp. seta /sɛta/  
“mushroom”

Measures: Spectral distances between /e/ and /ɛ/



# Study 2: Production results.

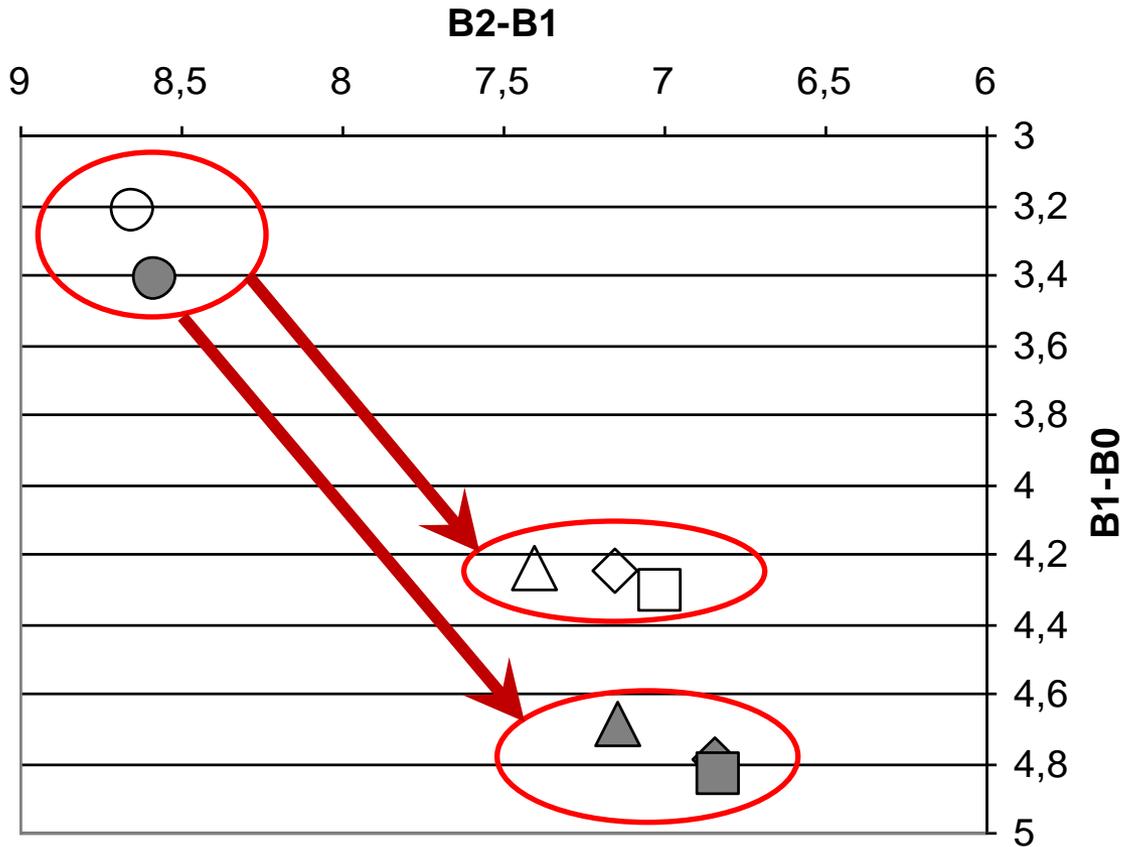
## Minimal pairs





# Study 2: Production. Results.

## Minimal Pairs, Cognates and Non-Cognates

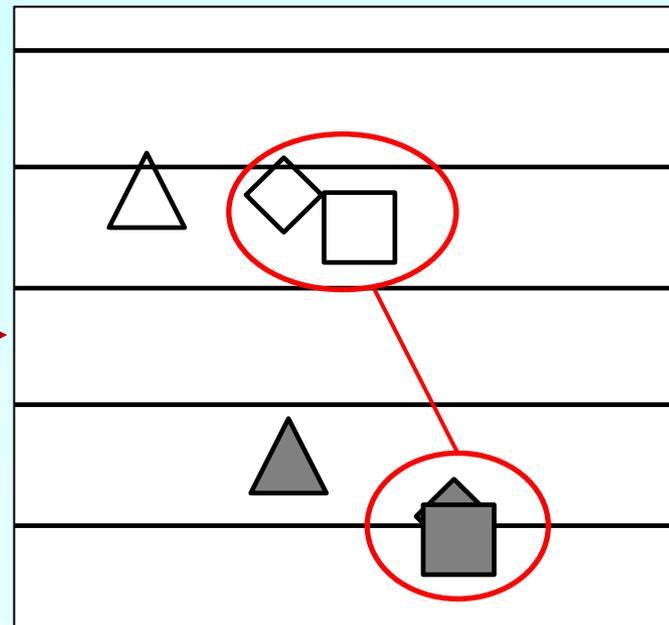
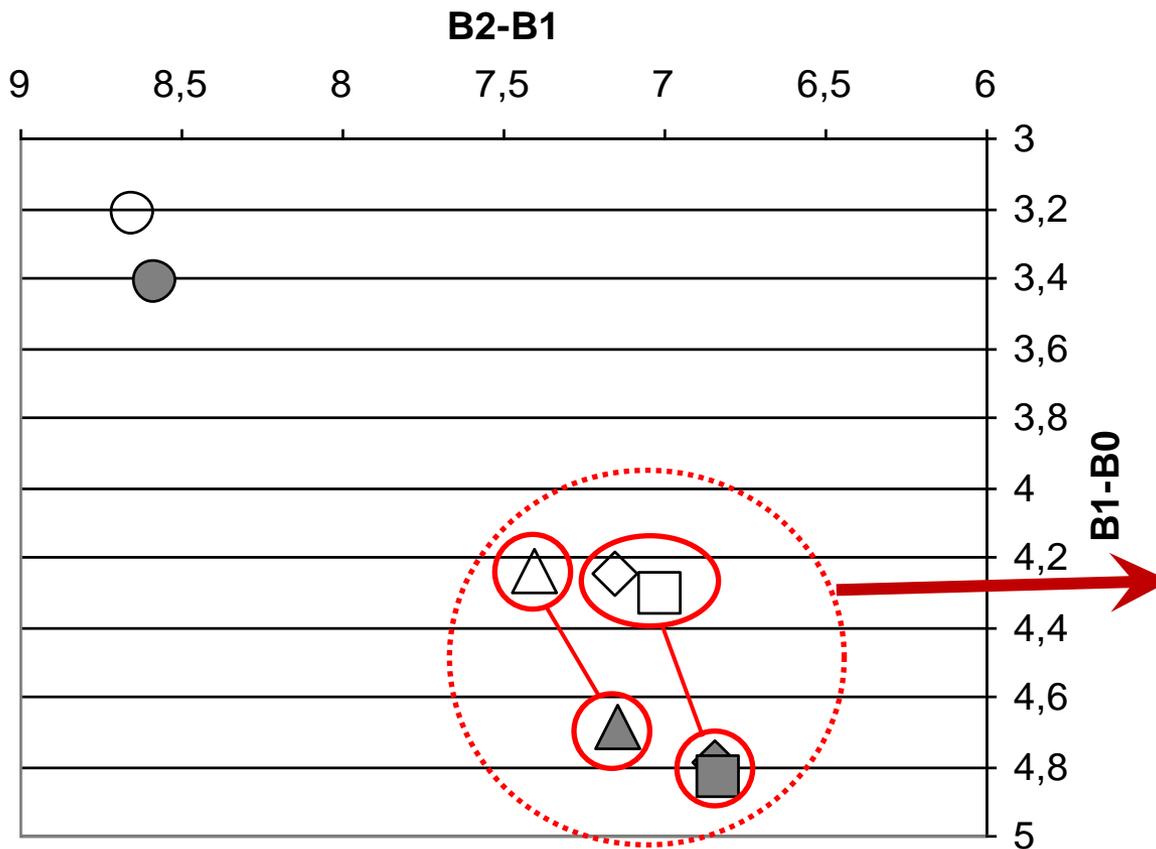


- |                                  |                                   |
|----------------------------------|-----------------------------------|
| —◇— /ε/ Cognates Low-CatUse      | —◇— /ε/ Cognates High-CatUse      |
| —△— /ε/ Minimal Pairs Low-CatUse | —△— /ε/ Minimal Pairs High-CatUse |
| —□— /ε/ Non-Cognates Low-CatUse  | —□— /ε/ Non-Cognates High-CatUse  |
| —○— /e/ Minimal Pairs Low-CatUse | —●— /e/ Minimal Pairs High-CatUse |



# Study 2: Production. Results.

## Minimal Pairs, Cognates and Non-Cognates



- |                                  |                                   |
|----------------------------------|-----------------------------------|
| —◇— /ε/ Cognates Low-CatUse      | —◆— /ε/ Cognates High-CatUse      |
| —△— /ε/ Minimal Pairs Low-CatUse | —▲— /ε/ Minimal Pairs High-CatUse |
| —□— /ε/ Non-Cognates Low-CatUse  | —■— /ε/ Non-Cognates High-CatUse  |
| —○— /e/ Minimal Pairs Low-CatUse | —●— /e/ Minimal Pairs High-CatUse |



## Study 2: Production results.

**Low CatUse group produced:**

- smaller spectral distance scores /e/-/ɛ/
- produced Cat /ɛ/ with significantly closer and fronter values (Spanish-accented) and did so to a significantly greater extent in cognates than in non-cognates.



## Study 1 + Study 2: overall conclusions

- Catalan /e/-/ɛ/ is a phonetically “weak” contrast, and this causes

(a) difficulty in acquisition.

(b) sensitivity to L1/L2 use

- The **cognate effects** found suggest that bilinguals may store merged phonetic categories that are malleable and sensitive to L1 & L2 experience and use

**The cognate effects that we found for the Low CAT users needs to be investigated further!**



## Plasticity

**So what does this research tell us about plasticity in speech perception and production in bilingualism?**

- The data suggests that patterns of L1/L2 exposure and use may affect phonological representations, leading to the weakening a contrast and eventually to a merged phonetic category.**
- Lexical representations may be unaffected by contrast weakening.**



# ***Thank you!***

## **Collaborators in this work:**

- Marianna Nadeu**  
(Penn State University)
- James L. Keidel**  
(Bangor University, UK)
- James E. Flege**  
(University of Alabama at Birmingham)

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# Method

## Categorization (ID)

The diagram shows the phoneme /e/ being categorized into two groups based on context. On the left, the lowercase letter 'e' is shown with a speaker icon above it. Below it, the number '100' is displayed in red on a black background, with the phonetic transcription /sen/ and the word 'cent' below it. Further down, a keyboard image highlights the 'e' key in red. On the right, the uppercase letter 'E' is shown with a speaker icon above it. Below it, the number '7' is displayed in green on a black background, with the phonetic transcription /set/ and the word 'seven' below it. Further down, a keyboard image highlights the 'e' key in green.

## Discrimination (DIS)

The diagram shows the phoneme /e/ being discriminated into two groups based on context. At the top, three boxes are shown: a red 'V', a white '¿V?' on a black background, and a green 'V'. Below these, two speaker icons are shown. Under the first speaker icon, the phonetic transcriptions /e/, /e/, and /ɛ/ are listed. Under the second speaker icon, the phonetic transcriptions /ɛ/, /e/, and /e/ are listed. Below the first set of transcriptions, three boxes are shown: a red 'V', a red 'V', and a green 'V'. Below the second set of transcriptions, three boxes are shown: a red 'V', a green 'V', and a green 'V'. At the bottom, a keyboard image has a red arrow pointing to the 'e' key and a green arrow pointing to the 'e' key.