

# Factors Affecting the Pronunciation of a Second Language



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Pronunciation Modeling and Lexicon Adaptation for  
Spoken Language Technology

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- ❖ NIDCD: The Development of Phonetic Categories
- ❖ NIDCD: Age Constraints on Second Language Acquisition



# To obtain a copy of this talk ...

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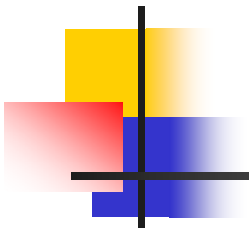
- ❖ jeflege@uab.edu  
(Powerpoint file via the internet)
- ❖ copies of bibliography at the back

# Outline of this talk



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1. Definition of foreign accent (FA)
2. Why examine FA?  
(effects of FA)
3. Scaling FA
4. Who has a FA?
5. Sources of FA



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# 1. Defining foreign accent (FA)



## FA defined

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- FA is due to the influence of the L1 phonetic/phonological system on production of L2 vowels and consonants, stress, rhythm and intonation (Burgess, 2001)



## FA defined

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- “Non-pathological speech produced by L2 learners that differs in partially systematic ways from the speech characteristics of native speakers (Munro, 1998: 139)
- Degree of FA depends on "the extent to which an L2 learner's speech is *perceived* to differ from native speaker norms" (Munro & Derwing, 1998: 160)



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## **2. Why study FA? (effects of FA)**



# Effects of FA

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## ***Negative evaluation***

- In matched guise studies, accented and unaccented versions of the same speech samples are presented (*Anisfeld et al., 1962; Arthur et al., 1974; Ryan & Carranza, 1975*).
- Listeners don't know they have heard the same talker twice, in different "guises"
- Accented samples are consistently rated less favorably on scales ranging from, e.g., kind-cruel or intelligent-stupid.



# Effects of FA

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## ***Misunderstanding of affect***

- Example from Cunningham-Andersson & Engstrand (1989, p. 139)
- A syntactic marker used in Lappish (a strong utterance-final F0 fall followed by a strong aspiration noise) is often used by Lappish speakers in Swedish
- This aspect of phonetic transfer is may be misinterpreted by Swedes as “an emotional expression of resignation”.

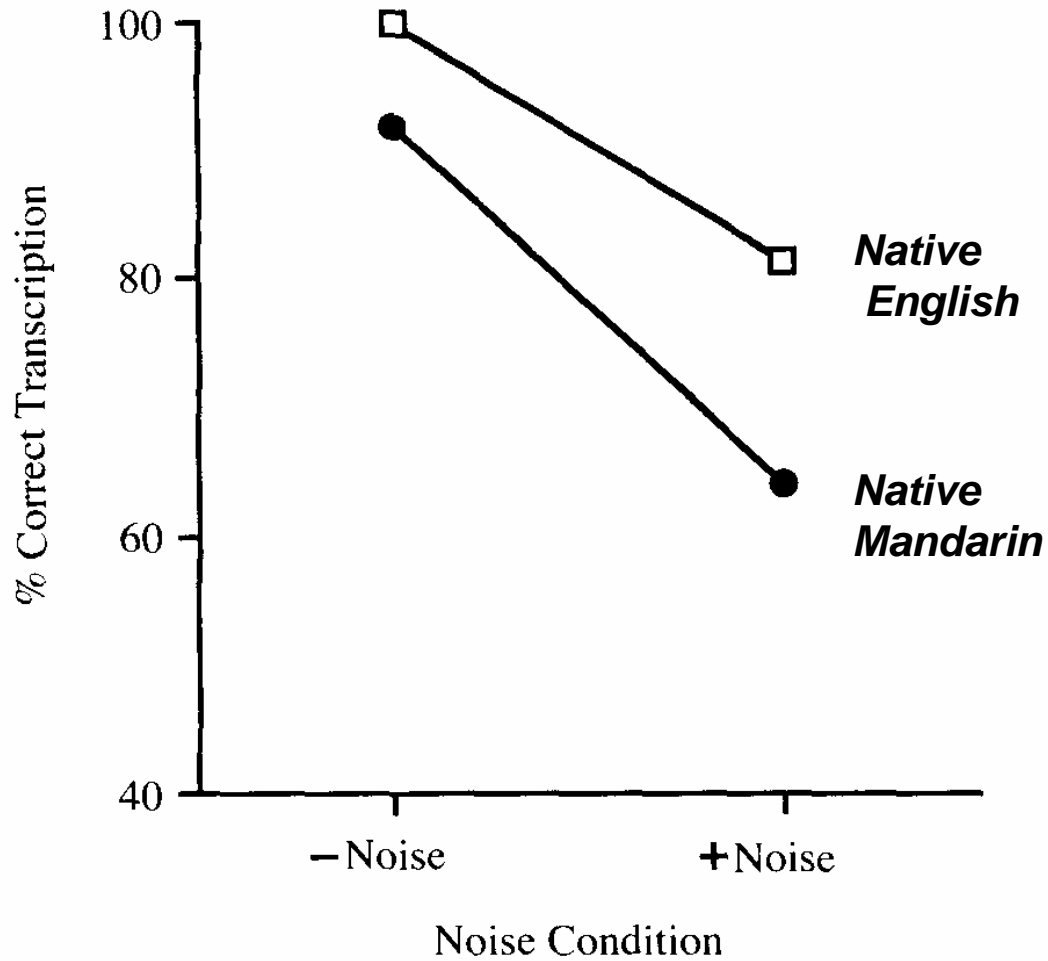


# Effects of FA: intelligibility

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- Foreign-accented speech is typically less intelligible than the unaccented speech of native speakers
- Munro (1998) examined the comprehension of sentences produced by native English and Mandarin adults
- Sentences presented for transcription in the quiet and in cafeteria noise (S/N = 7 dB).

# Munro (1998)



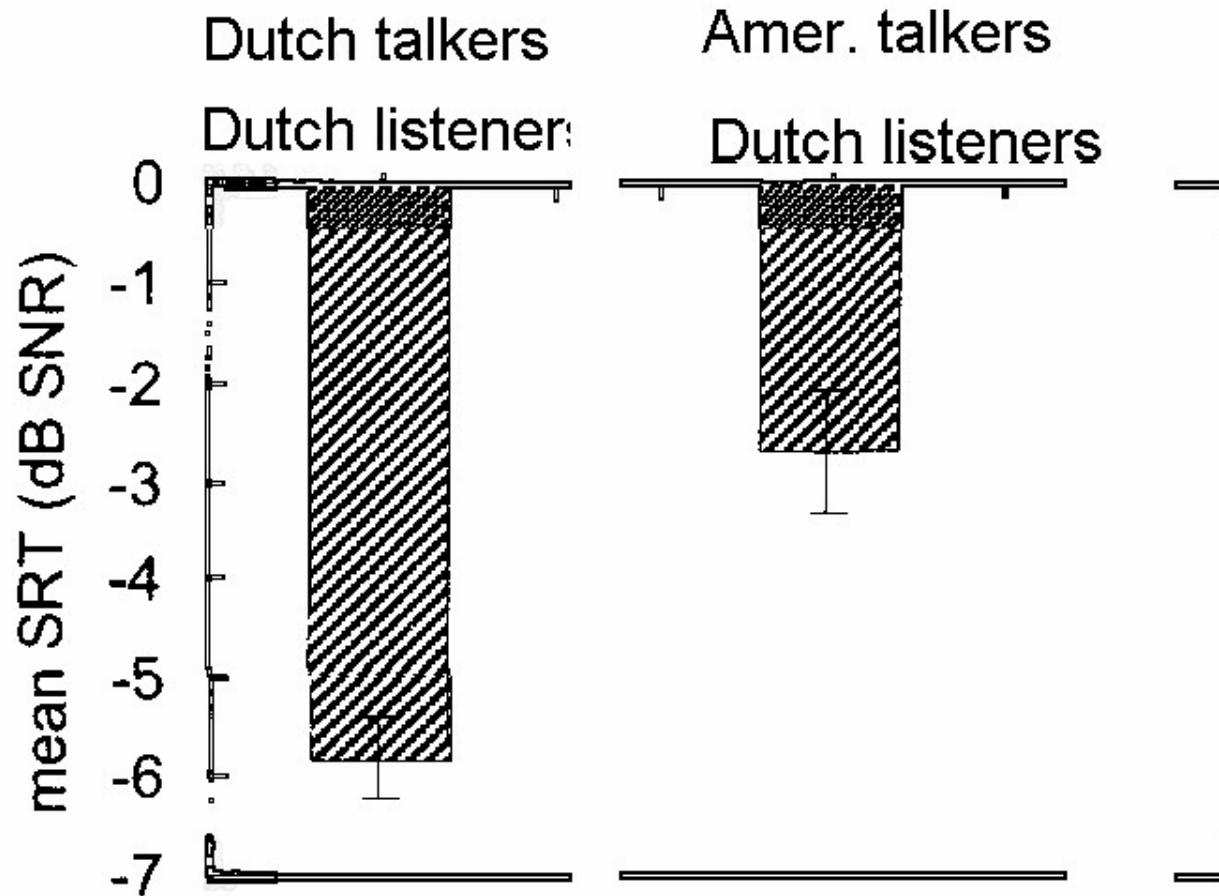


# Effects of FA: intelligibility

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- *Adding noise* seemed to have a slightly greater effect on foreign-accented than unaccented (native-produced) speech.
- Problem: NE group was at ceiling in the no-noise condition.
- Better measure of noise effect on nonnative speech is the Speech Reception Threshold (*SRT*) technique.
- DV = the S/N ratio at which 50% correct responses obtained for short, redundant, everyday sentences

# Van Wijngaarden (2001)



# FA $\neq$ intelligibility



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- Munro & Derwing (1995) examined FA and intelligibility in speech samples produced by 10 native Mandarin adults
- Most speech samples were “highly intelligible” but degree of FA varied considerably. Significant correlation between FA and intelligibility for only 5/18 listeners.
- Munro & Derwing (1997) examined 48 non-natives. Intelligibility-FA correlations observed for 20/26 listeners; mean  $r = -.46$ .

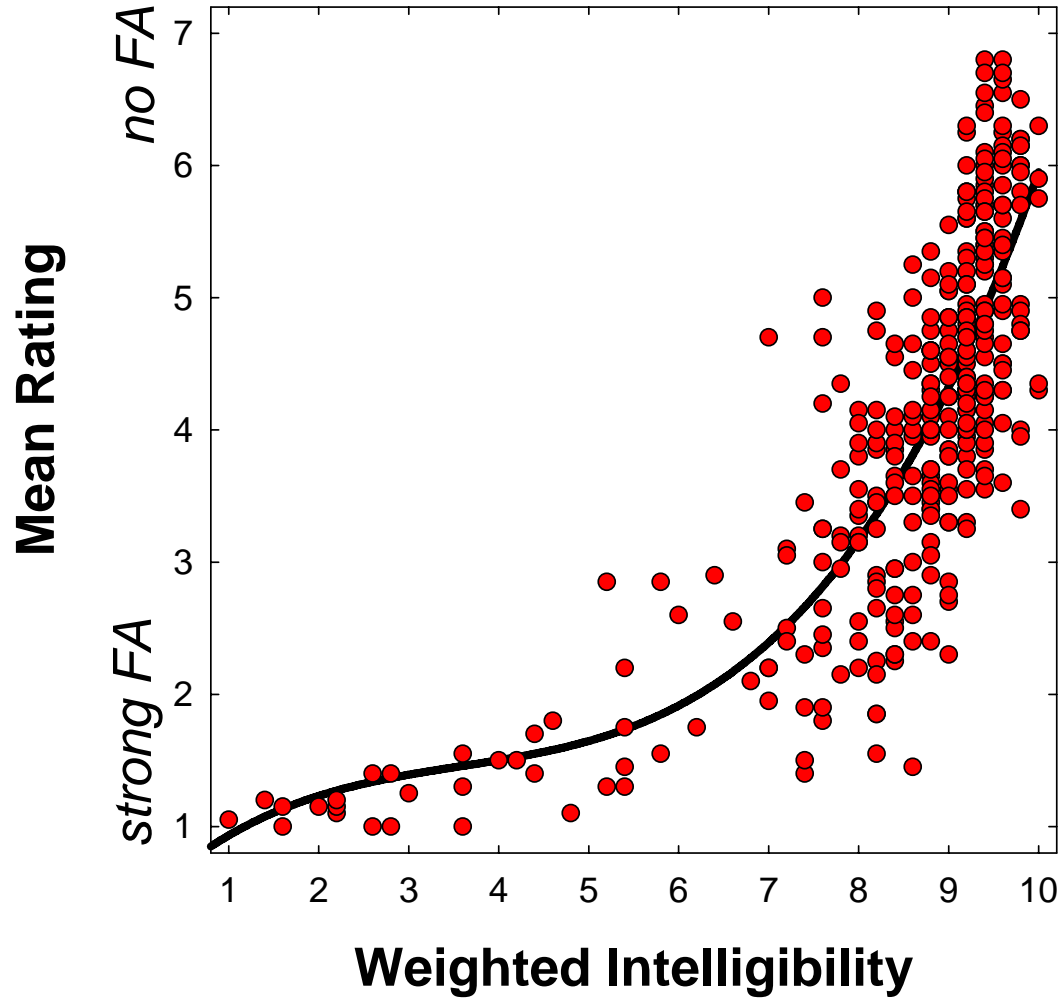


## FA $\neq$ intelligibility: Segments

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- Flege et al. (1995) examined word-initial /r/ and /l/ tokens spoken by native English and native Japanese adults
- Consonants identified and also rated (7-point FA scale) by NE listeners
- Significant difference between native English and Japanese groups for FA ratings but not intelligibility

# Intelligibility vs. FA in /r/ and // tokens





# Effects of FA: slowed processing

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- Three studies showed that even highly intelligible foreign-accented speech is processed more slowly than unaccented (native) speech
  - Munro & Derwing (1995b)
  - Schmid & Yeni-Komshian (1999)
  - Clark (2002)
- Probably due to mismatch between vowels and consonants in foreign-accented speech and native listeners' long-term memory representations



# Effects of FA: slowed processing

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- Munro & Derwing (1995b) examined sentences produced by native English and Mandarin adults
- The sentences were either True (e.g., *Elephants are big animals*) or False (e.g., *Most people wear hats on their feet*).
- The sentences were transcribed correctly (100% intelligible).



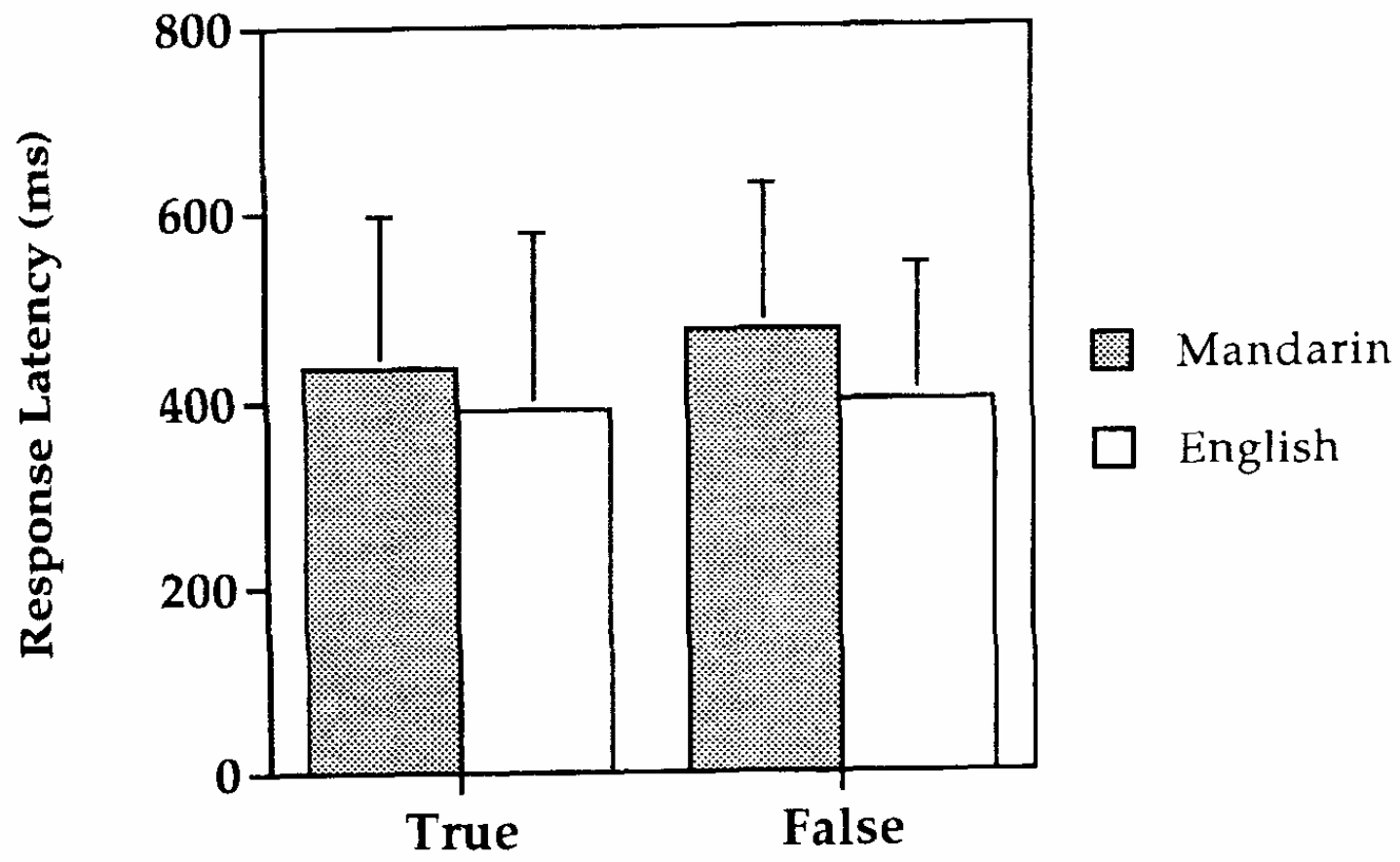
# Effects of FA: slowed processing

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- Task: respond T or F as rapidly as possible
- DV = the time needed respond (only correctly “verified” sentences examined)
- Significantly faster responses to unaccented than accented sentences (M = 62 msec)

# Sentence verification task, results

*M. J. Munro and T. M. Derwing*



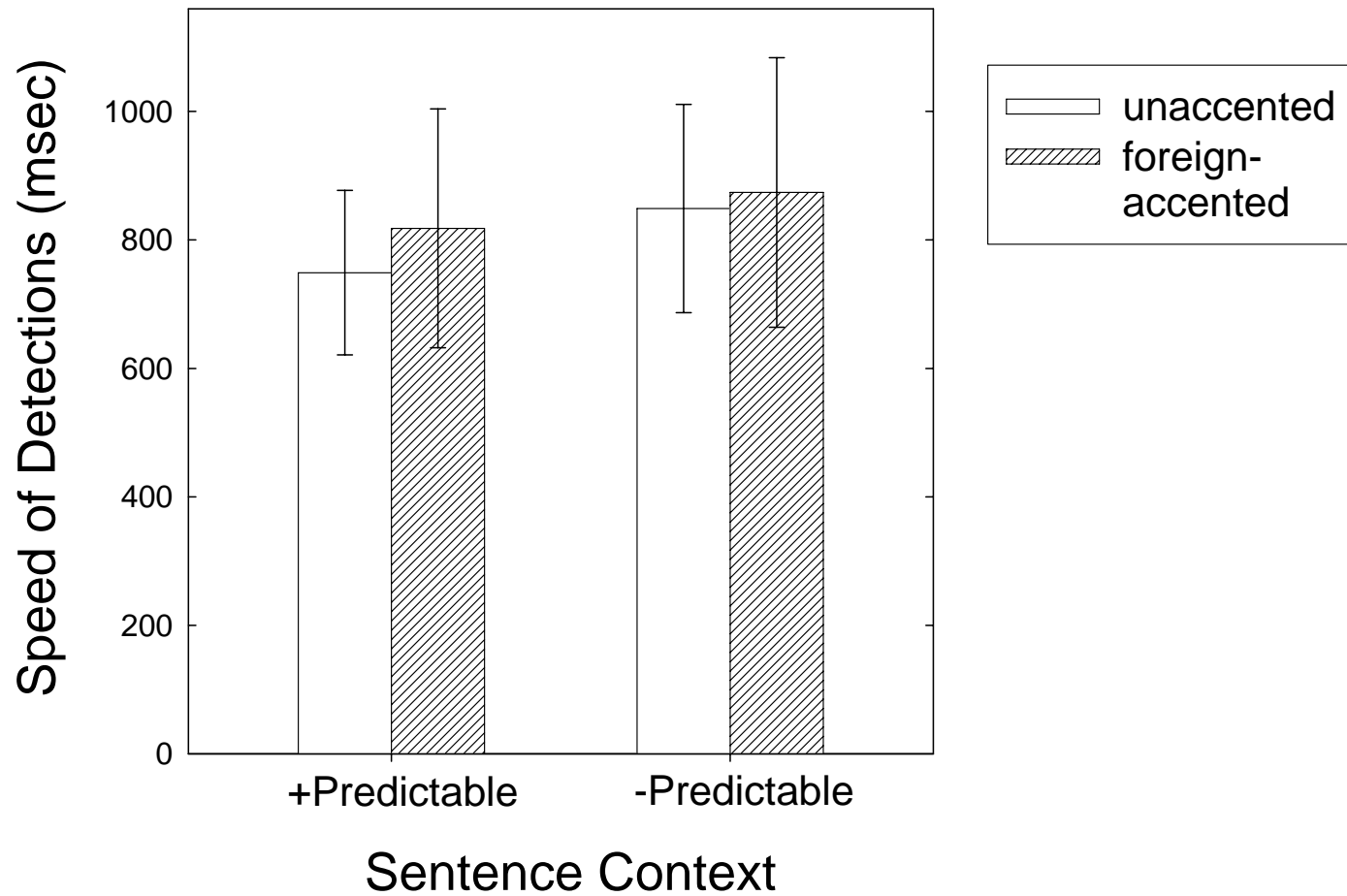


# Effects of FA: slowed processing

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- Schmid & Yeni-Komshian (1999) examined native English listeners' ability to detect intentional mispronunciations of words (e.g., “crib” → “grib”)
- High- and low-probability SPIN sentences produced by 4 native and 4 non-native speakers of English
- DV: speed of detection

# Speed of detection





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## 3. Scaling FA



## Ways to assess FA

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- Generate scores using an automatic testing system based on *speech recognition* technology (e.g., Neumeyer et al., 2000; Cucchiarini et al., 2000)
- Make specific *acoustic measurements* (e.g., VOT in stop consonants; Major, 1987)
- Global ratings of trained or untrained *listeners*



# Assessing FA

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- Perceptual effect of measured native-nonnative acoustic phonetic differences is uncertain
- Therefore, *listener judgments remain the “gold standard”*

# Scaling FA: Listener judgments



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1. Have Ss repeat standard set of simple sentences following a filled delay (“delayed repetition” technique)
  - ❖ Provides specific prosodic model
  - ❖ Yields fluent utterances (no pauses, prolongations, repetitions)
  - ❖ Prevents listeners from being influenced by lexical & semantic errors (e.g., Derwing & Munro, 1997)

# Scaling FA



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2. Present productions of each sentence in separate counterbalanced blocks.

Make sure that the sentences examined contain a wide range of L2 vowels and consonants

# Scaling FA



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3. Randomly present productions of each sentence 4 times each. Take the median of the last 3 replicate judgments.
  - ❖ Why? Obtain stable FA ratings of each sentence from each listener

# Scaling FA



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- ❖ As native-speaking listeners grow familiar with a FA, it becomes more intelligible (e.g., Wingstedt & Schulman, 1987; Bradlow & Bent, 2001; Clark, 2002 ).
- ❖ As native-speaking listeners grow familiar with non-native speech, it may be judged as more strongly foreign-accented (Flege & Fletcher, 1992; Munro & Derwing, 1994)

# Scaling FA



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4. Include native speakers as controls, and to anchor listeners' ratings of nonnative speakers
  - ❖ FA ratings are not absolute. Flege & Fletcher (1992) showed that FA ratings are range-dependent
  - ❖ Example: Someone with a mild FA might appear to have a stronger FA if presented in a set with many native speakers

# Scaling FA



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5. Use mature native speakers as listeners
  - ❖ The ability to gauge degree of FA may develop in children learning English as their native language (Scovel, 1988)
  - ❖ Non-native listeners may not rate foreign accent in their L2 like native speakers of that language (Flege, 1988)



## Flege (1988)

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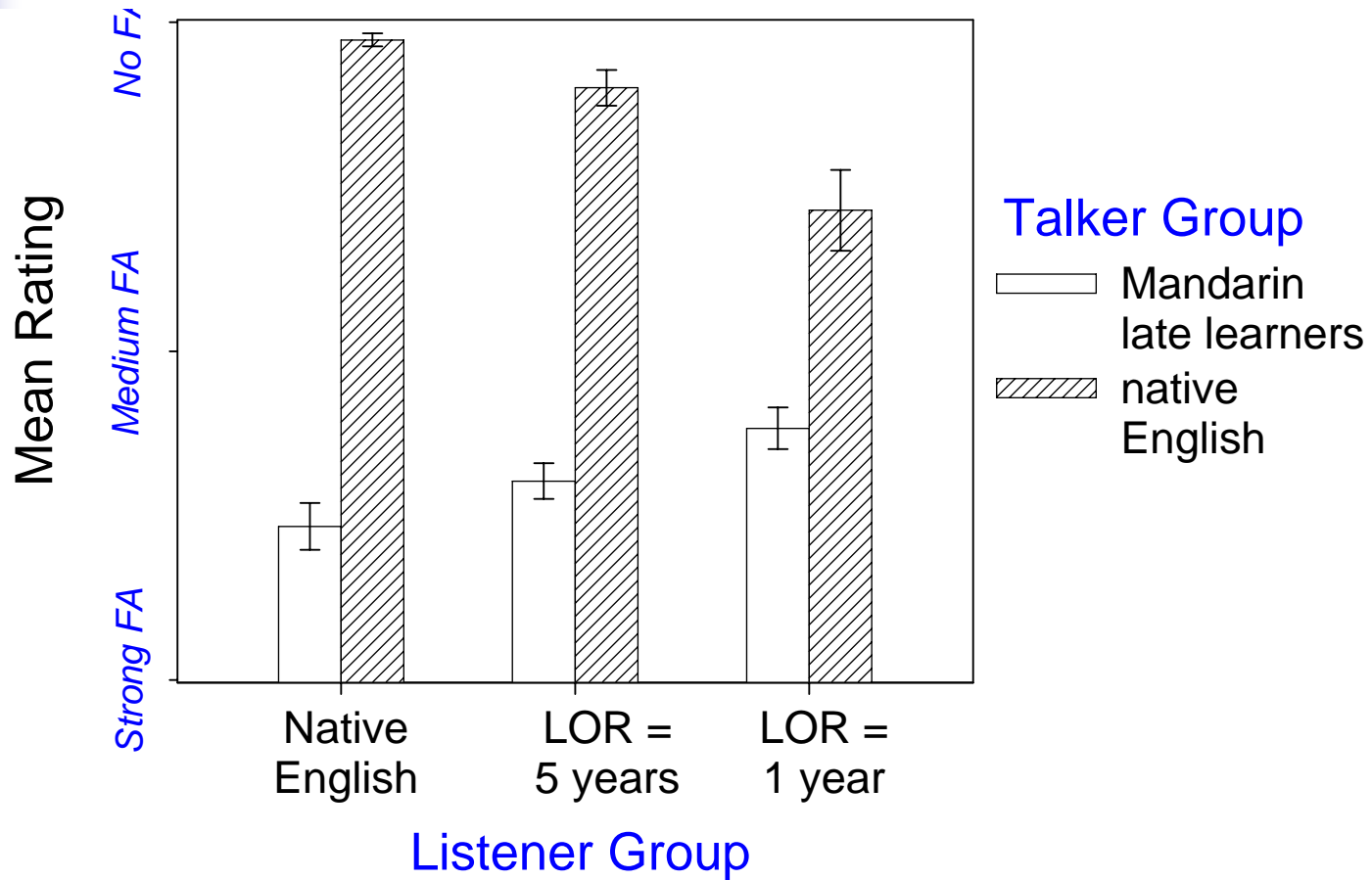
- Examined FA in English sentences spoken by native speakers of English and Mandarin adults
- Sentences rated for FA by three groups of listeners:

*Native English*

*Native Taiwanese, LOR = 1 year*

*Native Taiwanese, LOR = 5 years*

# Flege (1988)





# Scaling FA

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6. **Control for listener variability**
  - ❖ “Talker” analysis: average rating for each talker based on ratings given by multiple listeners
  - ❖ “Listener” analysis: average rating for each listener based on ratings given to all talkers in each group



# Scaling FA

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7. Use rating scale with sufficient resolution
  - ❖ Southwood & Flege (1999) provided evidence that FA is a metathetic continuum amenable to scaling using an EAI scale;
  - ❖ a 7-point scale may be insufficient (9-point or continuous may be better)



# Scaling FA: reliability

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- Reliability refers to the “degree to which test scores are free from errors of measurement” (Committee to Develop Standards for Educational and Psychological Testing, 1985).
- Evidence of measurement error: difference in FA ratings when there is little likelihood that FA should have changed (Elliott, 1995).



## Scaling FA: reliability

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- Flege & MacKay (cited by Piske et al. 2001) recorded 62 Italian-English bilinguals at 2 times separated by 4 years
- No reason to expect a FA difference between Time 1 (1992) and Time 2 (1996)
  - ❖ The bilinguals had lived in Canada for 32 years at T1
  - ❖ They used Italian about the same amount at T1 and T2 (22% vs. 24%)





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## 4. Who has a FA?



## Who has a FA?

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Many variables influence FA (see, e.g., Flege, 1998, and Piske et al., 2001), including:

- ❑ *Age at first exposure to the L2*
- ❑ *Years of L2 use*
- ❑ *Amount of L2 and L1 use*
- ❑ *Type of L2 input (native speaker vs. foreign-accented non-native speakers)*
- ❑ *Motivation (?)*
- ❑ *Gender (?)*



## Who has a FA: Age

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Chronological age (CA) of first extensive exposure to an L2 is related to other factors likely to influence L2 speech learning, including

- ❑ *State of neurological development*
- ❑ *State of development of the L1 phonetic system*
- ❑ *Kind/quality of L2 input*
- ❑ *Motivation*



# Who has a FA? Child L2 learners

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- As discussed by Snow (1987, p. 192), there is widespread belief that children who learn a second language (L2) do so *"quickly, automatically, effortlessly, and to a level indistinguishable from that of native speakers"*
- However, relatively few studies have directly compared adult and child L2 learners

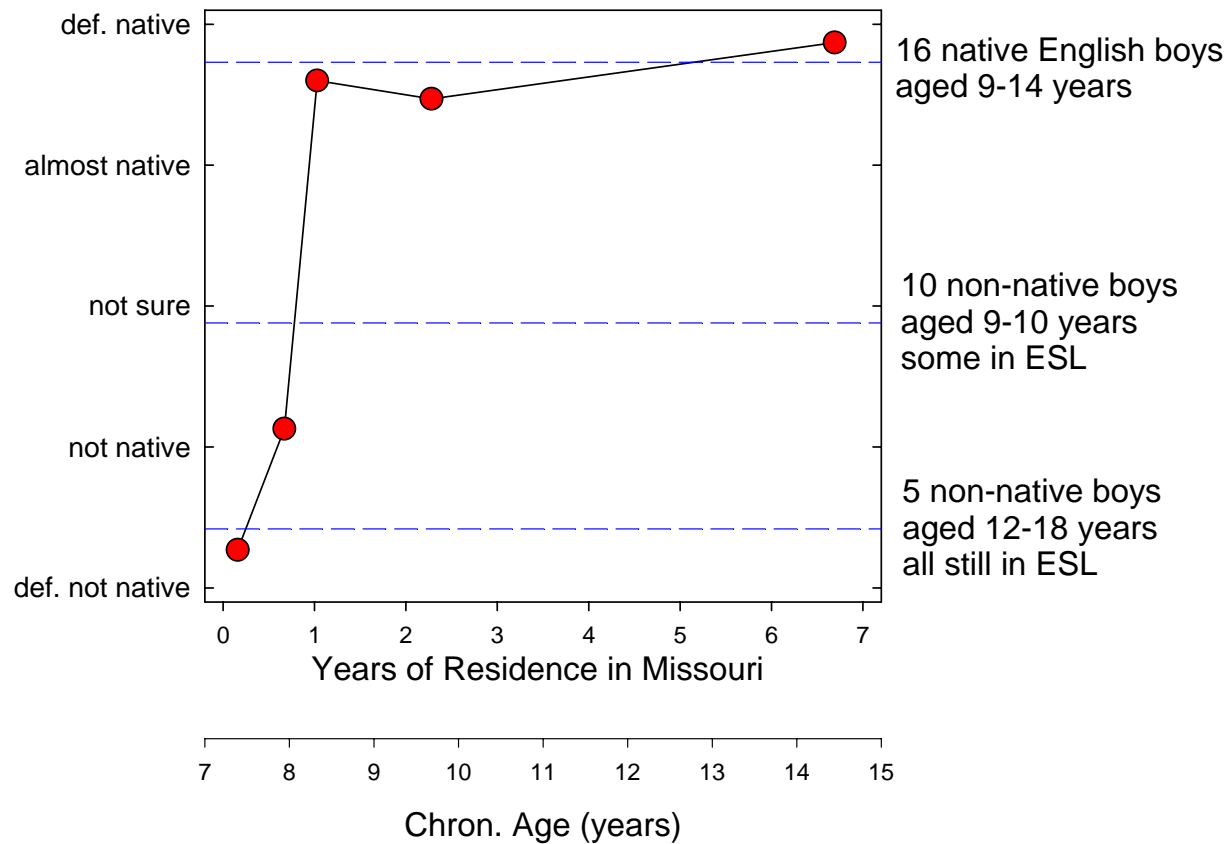


## Winitz et al. (1995)

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- Supported the view that children learn L2 pronunciation rapidly and accurately
- Longitudinal study of a Polish boy who arrived in the United States at the age of 7 years
- Recorded over a 7-year period

# FA ratings for Polish boy





## Child L2 learners

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- Results may not generalize to other immigrant children learning English in the US (The boy may have received little or no foreign-accented input )
- Two recent studies examining immigrant adults and children showed that children make more progress than adults, but may retain a FA
  - Aoyama & Flege (unpubl.)
  - Flege et al. (unpubl.)

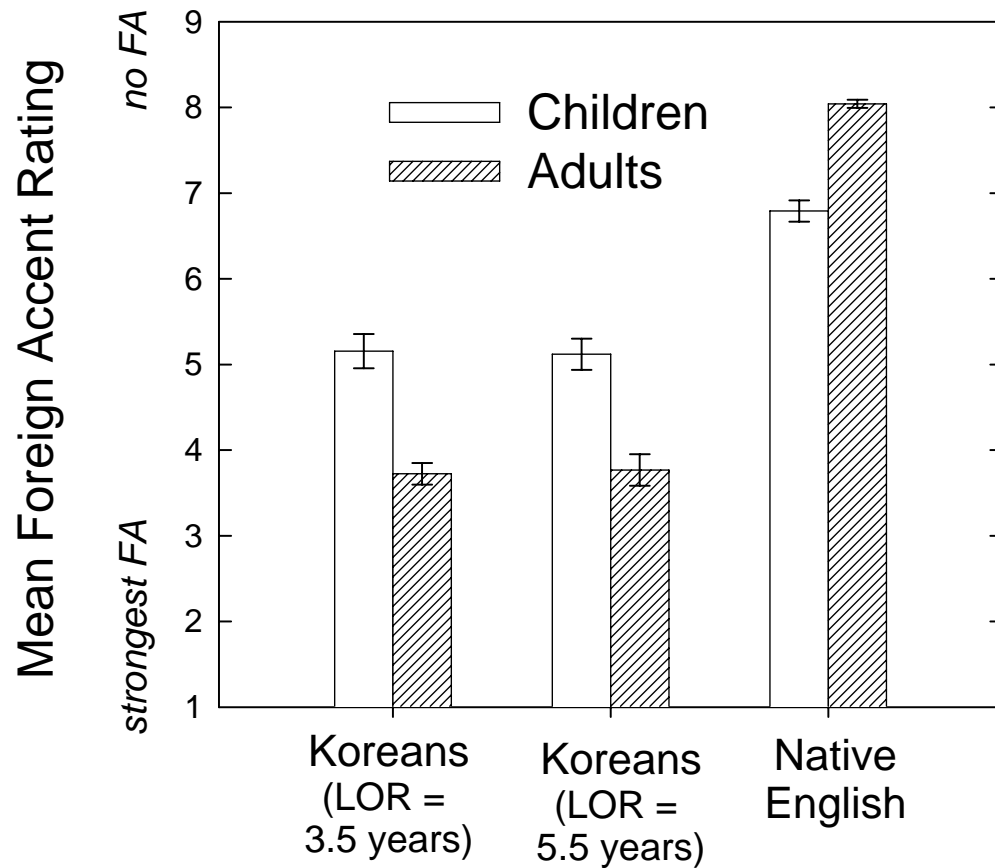


## Korean study (Flege et al., unpubl.)

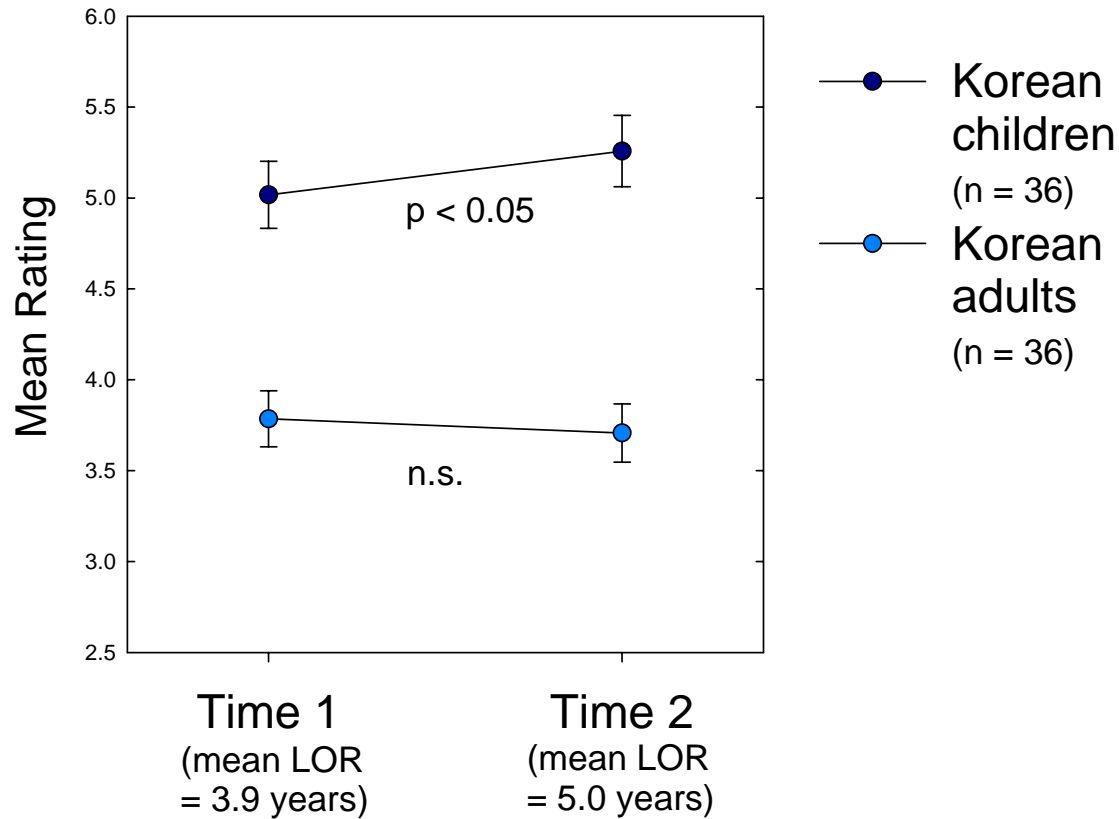
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- Examined native Korean (NK) children and adults
- NK participants compared to age-matched native English speakers
- All groups tested at 2 times separated by 1 year

# FA ratings averaged over T1 and T2



# FA averaged over the Korean LOR groups



# Child L2 learners

- Children seem to learn L2 pronunciation faster/better than adults
- However, they are likely to retain a FA, even after 5 years of daily L2 use
- This conclusion may hold true only for child L2 learners who continue using the L1 often and hear the L2 spoken with a FA by others
- Do typical immigrant children retain a FA indefinitely?

# Retrospective Developmental Designs



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- Two studies each examined large number ( $n = 240$ ) of immigrants to North America
- One study examined Italians in Canada, the other Koreans in the US
- All participants were adults who differed according to age of arrival
- Long residence in North America (mean = 32 years for Italians, 15 years for Koreans)

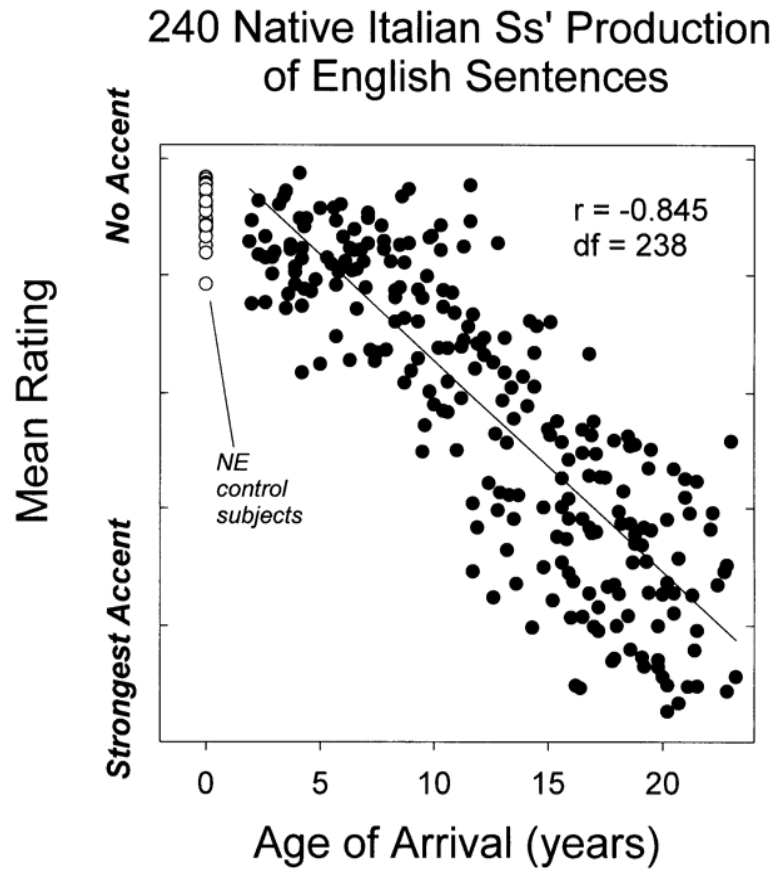
# Question addressed



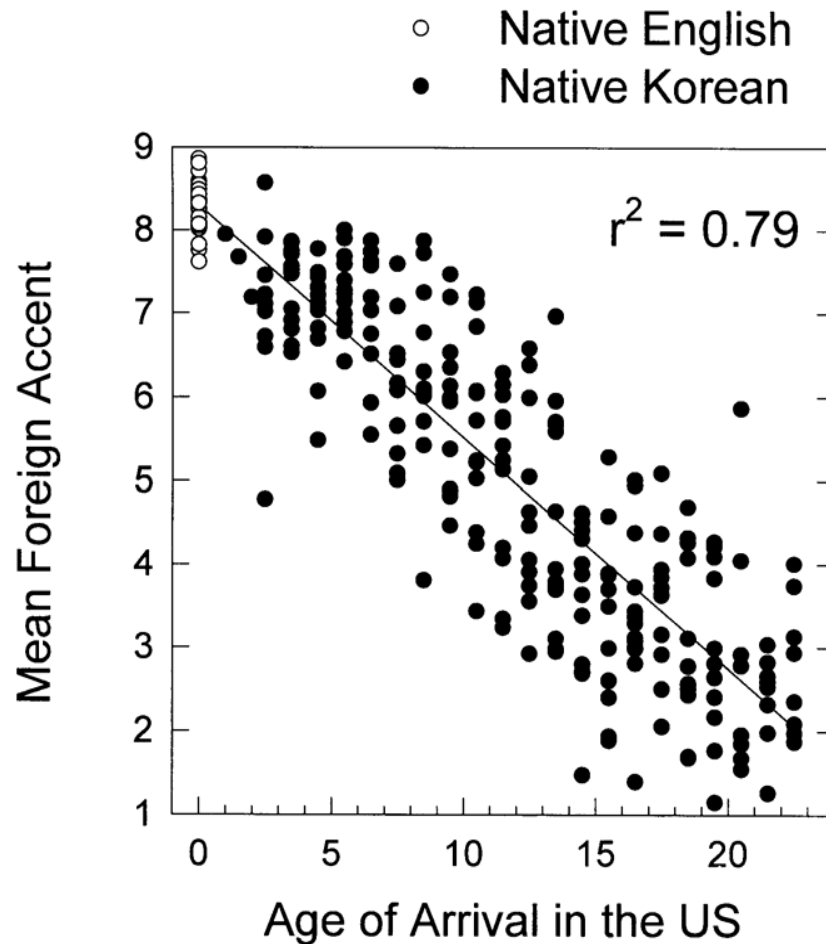
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- Would there be a sharp increase in strength of FAs at an AOA of 12 or 13 years?
- Would all late learners have detectable FAs?
- Would all early learners evade detection as foreign-accented?

# Italian-accented English (Flege et al. 1995)



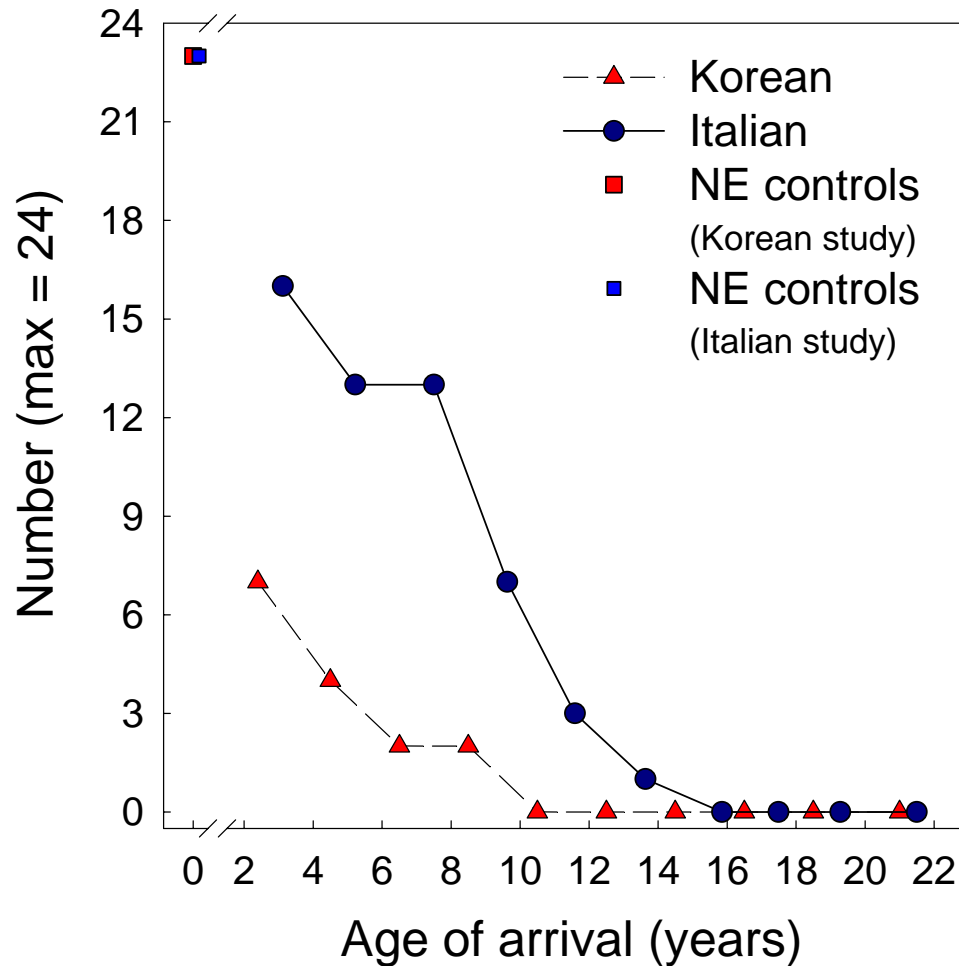
# Korean-accented English (Flege et al., 1999)



# Who speaks without FA?

- Determine if each Italian or Korean received a FA rating that fell within 2 standard deviations (SDs) of the mean rating obtained for the native English group ( $n = 24$ )
- In both studies, non-natives assigned to one of 10 subgroups based on AOA (24/subgroup)
- Determine how many non-native subjects in each AOA group met the 2-SD criterion

# N of subjects per group (max = 24) without a FA





## Retrospective Designs: Conclusions

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- No evidence of a non-linearity in the AOA-foreign accent function for either group
- Virtually all participants with AOA > 15 years had a detectable FA
- Most early learners had a better pronunciation than most late learners
- However, many participants with AOA < 10 years had a detectable FA

# Interpreting age effects ...

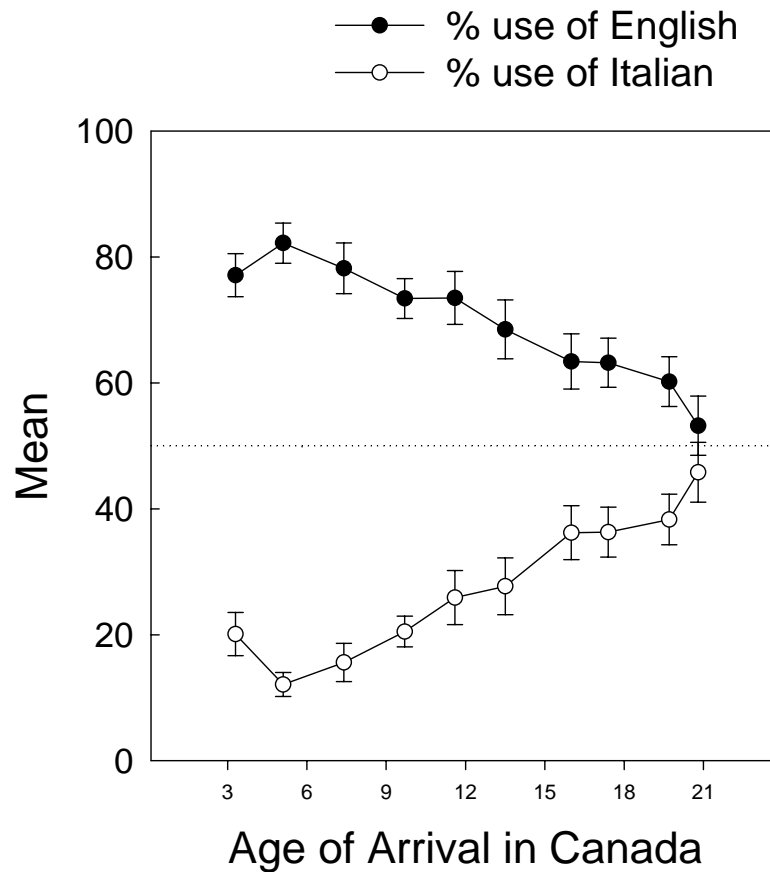


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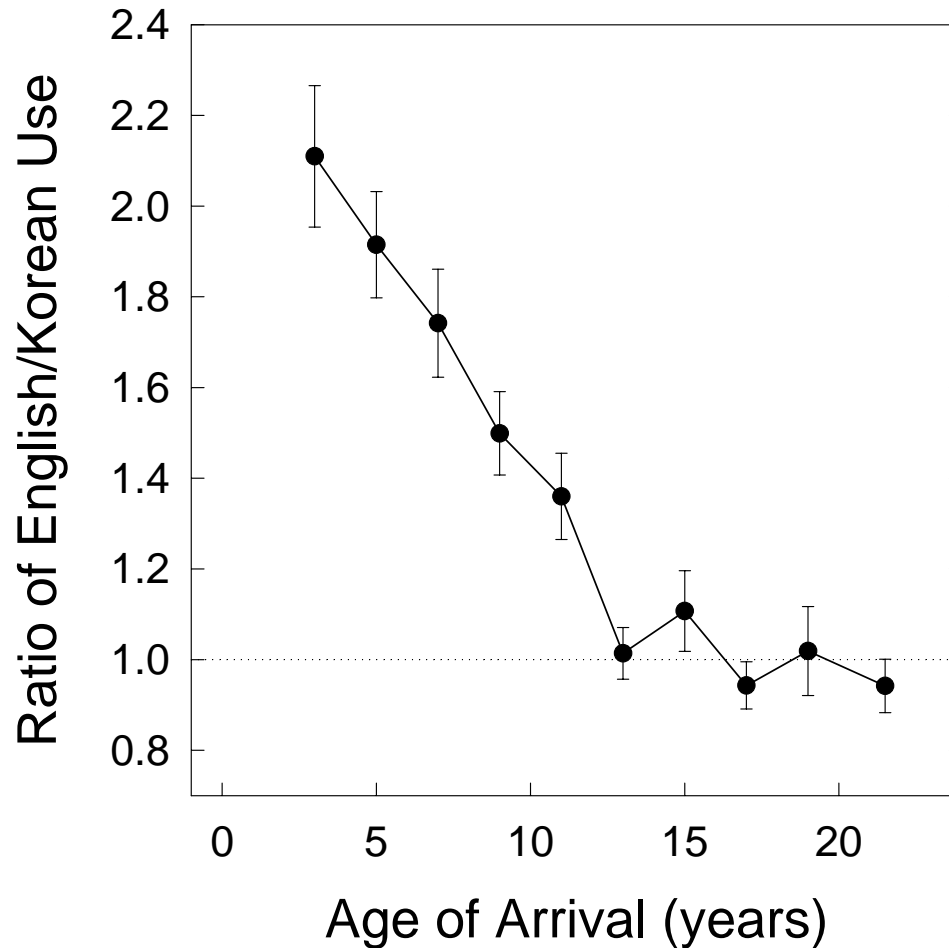
is difficult because AOA is confounded with many factors

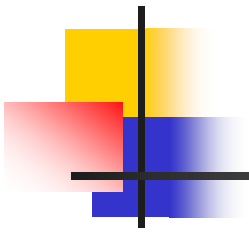
- ❑ *LOR* (the longer the better)
- ❑ *Years of education* in US/Canada (the more the better)
- ❑ *English use* (the more then better)
- ❑ *L1 use* (the more the worse)
- ❑ And possibly other things (motivation, amount of foreign-accented input)

# Relation between Italian-English bilinguals' L1 & L2 use and AOA



# Relation between Korean-English bilinguals' L2/L1 use and AOA

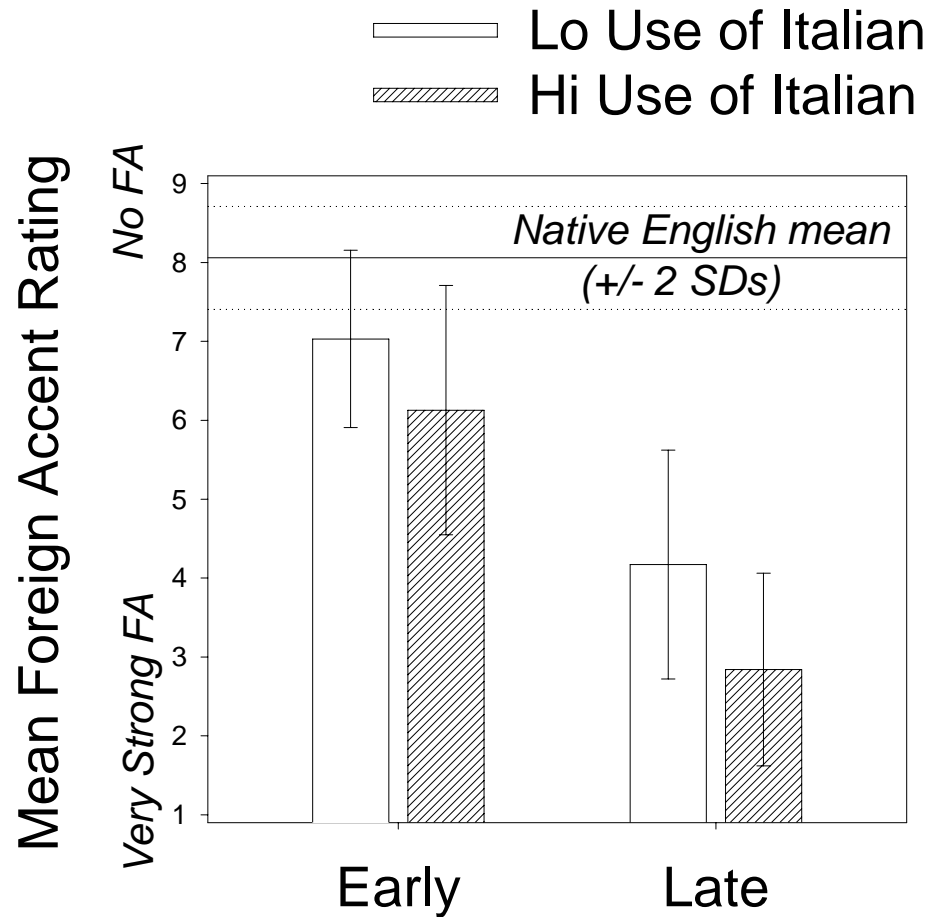




## Piske et al. (2001) examined early and late bilinguals who differed in L1 use

	Age of arrival in Canada (years)	% Italian use	Length of residence in Canada
<b>Early-low % Italian use</b>	7	7%	42
<b>Early-high %Italian use</b>	8	43%	40
<b>Late-low % Italian use</b>	20	10%	31
<b>Late-high % Italian use</b>	20	53%	29

# Results of Piske et al. (2001)





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## 5. Sources of FA

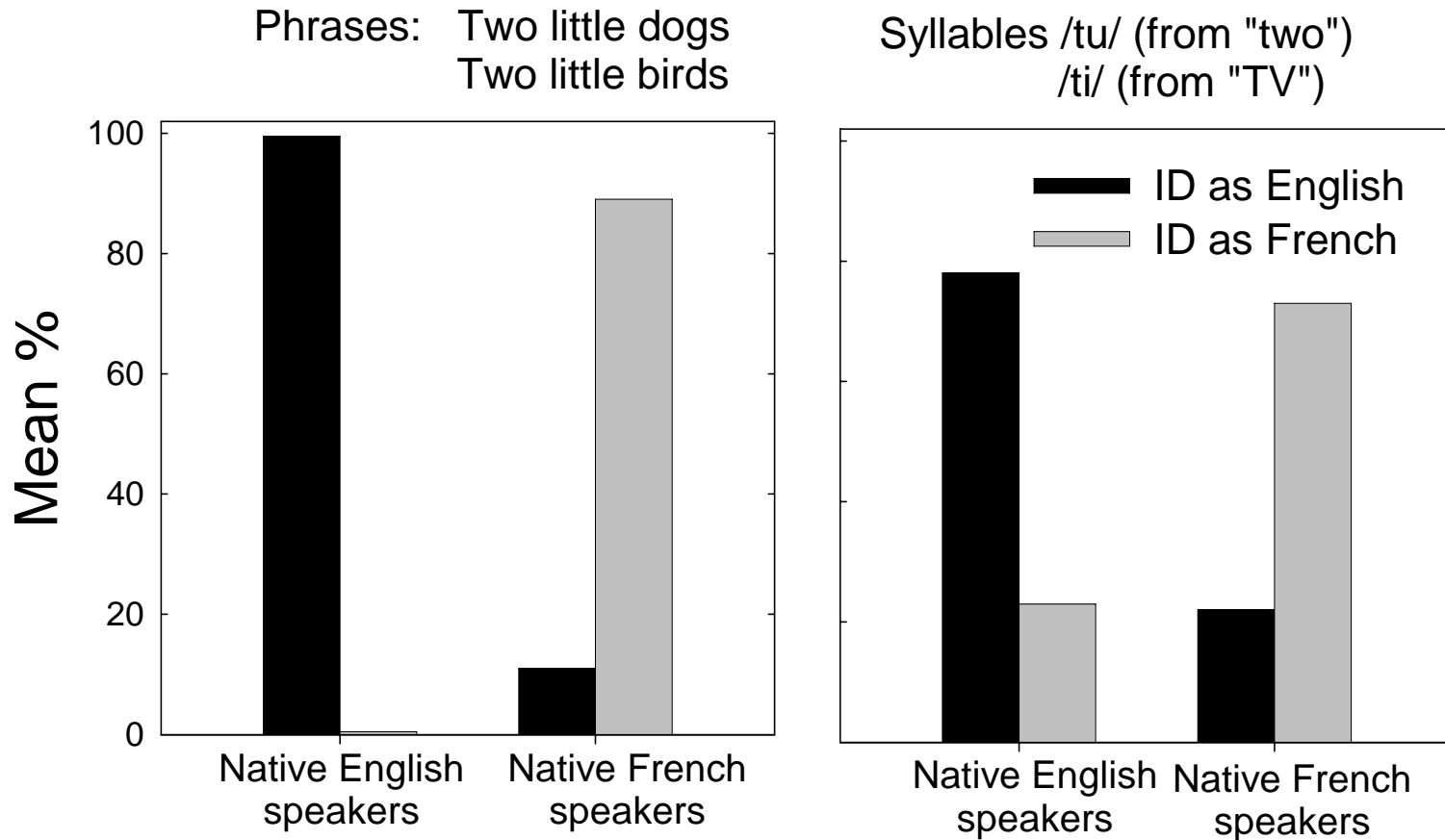


# Detection of foreign accent

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- Flege (1984) examined the ability of native English listeners to detect French foreign accent
- English phrases and syllables produced by native English and French adults
- Listeners identify speech samples as “English” or “French”

# Flege (1984)



# Detection of foreign accent



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- Flege (1984) examined shorter excerpts of speech in paired comparison experiments
- Two stimuli presented on each trial, one produced by native English talker, the other produced by a native French talker
- Listeners' job: determine which of the 2 stimuli was produced by a non-native (French) speaker

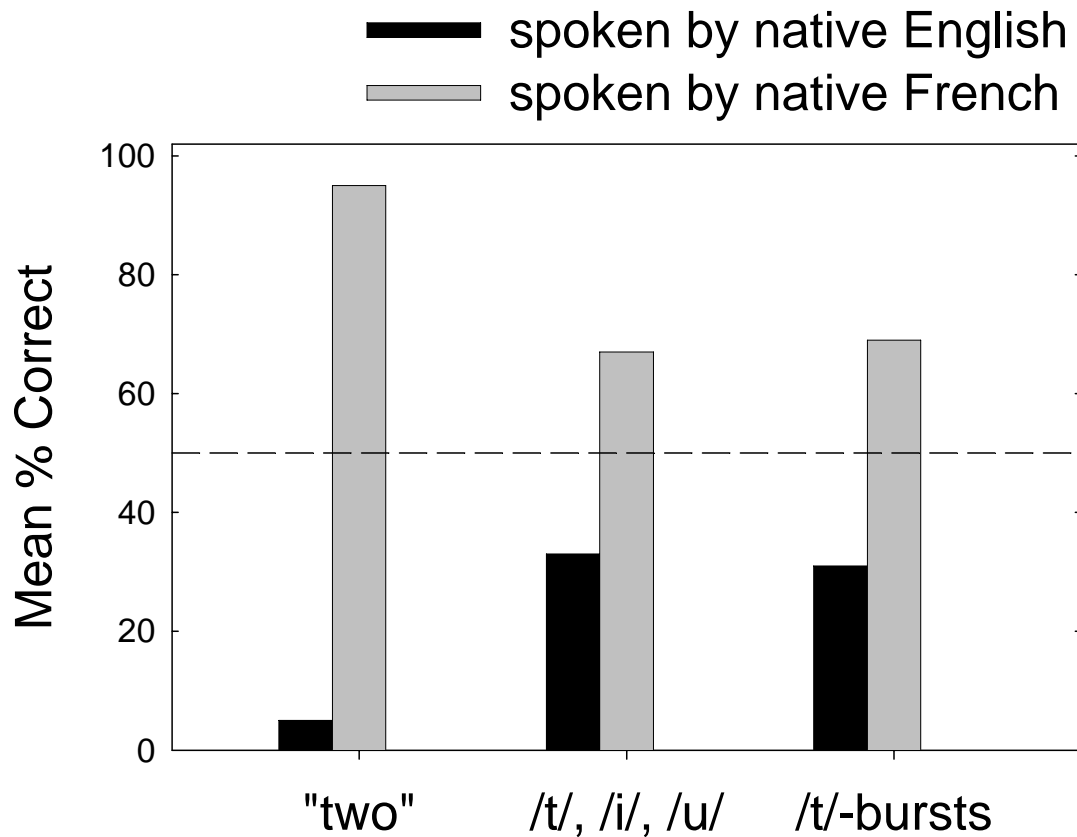
# Detection of foreign accent



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- Stimuli examined in three experiments
  - The word “two”
  - A single segment (/t/, /i/ or /u/) in cross-spliced CV syllables
  - The first 30 msec of /t/ release bursts
- Correct response rate always exceeded a chance level (50%)

# Flege (1984)



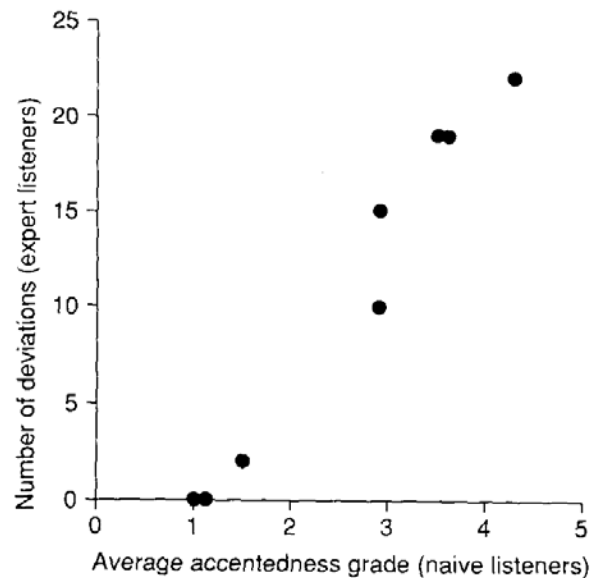


# Sources of FA: segmental errors

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- A number of studies examined the relation between degree of FA and number of overt segmental errors (e.g., Brennan & Brennan, 1981; Major, 1986; Anderson-Hsieh et al., 1992).
- Studies varied according to what kinds of errors were counted (phonemic vs. phonetic; a specified subset of possible errors; just one type)
- However, all showed significant correlations between number of errors and degree of FA

# N of segmental errors—FA ratings for 8 non-natives given by naïve listeners, $r = .99$ (C-A & Eng-strand, 1989)



**Fig. 1.** Relationship between naïve and expert accentedness judgements; the x-axis represents the average grade assigned to the reading by the naïve listeners (1–5), and the y-axis represents the number of deviant pronunciations noted by at least 2 expert listeners for each reading.



# Magen (1998)

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- Examined English sentences produced by native Spanish adults
- Used editing technique to “fix” particular segmental and prosodic errors
- Presented original and “fixed” sentences to native English listeners
- In many cases, the “fixed” sentences received higher ratings, indicating less FA

## Examples of corrections that significantly lessened FA (Magen, 1998)

- “eschool” → “school” (remove epenthetic vowel)
- “plann” → “planned” (insert final /d/)
- “sheep” → “ship” (repair lax vowel)
- “stand” → “stands” (add omitted /z/)
- “chirt” → “shirt” (affricate to fricative)
- lexical stress (ig-NOR-ant → IG-nor-ant)
- phrasal stress (next to HIM → NEXT to him)

# Flege and Munro (1994)



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- Detailed examination of sources of FA in the word “taco”
- Examined how “taco” was produced by native English speakers and Spanish/English bilinguals
- Began with a cross-language study which compared production of “taco” by Spanish and English monolinguals

# Flege & Munro (1994)

	<i>English monolinguals</i>	<i>Spanish monolinguals</i>
<i>a) Voice onset time of /t/</i>	58 ms	18 ms
<i>b) closure duration /k/</i>	73 ms	108 ms
<i>c) duration /o/</i>	149 ms	63 ms
<i>d) intensity /o/</i>	-0.9 dB	-5.3 dB
<i>e) F2 onset /o/</i>	1483 Hz	866 Hz
<i>f) F2 offset /o/</i>	1287 Hz	841 Hz



## Flege & Munro (1994)

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- Perceptual evaluation of productions of “taco” in English or Spanish by monolinguals
- Also: tokens produced in Spanish and English by early and late Spanish-English bilinguals
- Native English listeners classified the tokens (“Spanish” or “English”) and rated them on a 7-point scale (Spanish to English).



## Flege & Munro (1994)

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- Detailed acoustic analysis of the “taco” tokens
- Multiple regression analyses examined relation between the acoustic measurements and listener judgments.
- Accounted for 82% of the variance in classifications, 97% of the variance in ratings

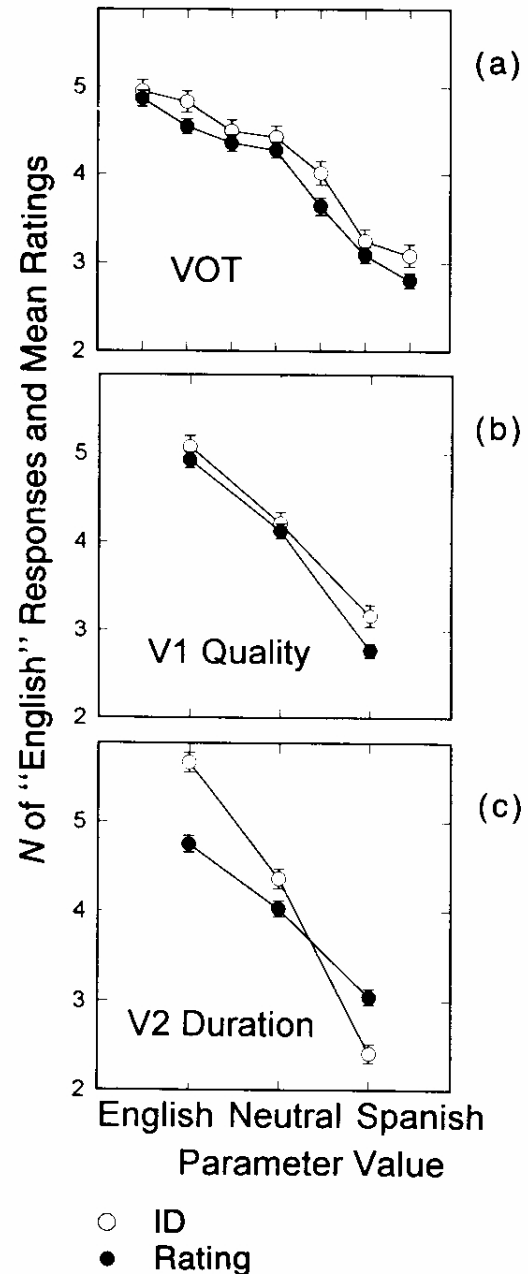


# Synthetic speech experiment

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- Create Spanish-English “taco” continuum which varied
  - (a) VOT of /t/
  - (b) spectral quality of first vowel
  - (c) duration of the second vowel

Effect of manipulation of 3 parameters on % identification as “English” (or mean ratings as “English”)





# Possible prosodic sources of FA

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1. incorrect lexical stress and associated difficulty in vowel reduction (e.g., Archibald 1992, 1993a,b,c; Fokes et al. 1984; Adams & Munro 1978; Flege & Bohn 1989)
2. incorrect stressing of function words and other unstressed words and syllables, which contribute to the perception of overall rhythmic differences (Bannert 1984; Adams & Munro 1978)
3. incorrect phrasal accentuation (Levitt 1991)



# Possible prosodic sources of FA

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4. incorrect pitch accent (Schmid 1986)
5. use of incorrect intonation patterns to mark specific meanings (Grover et al. 1987; Lepetit 1989; Shen 1990)
6. pitch ranges that are either too great or too narrow for the L2 (Backman 1979; Willems 1982; Shen 1989, 1990).



# Segments vs. prosody?

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- Anderson-Hsieh et al (1992) obtained global pronunciation ratings of paragraphs read by 60 non-natives.
- Stronger correlation between the global pronunciation ratings and ratings of prosody,  $r(58) = .90$ , than number of segmental errors,  $r(58) = 0.67$ .
- Problem: didn't demonstrate that the three trained listeners were able to evaluate prosody independently of segmental errors

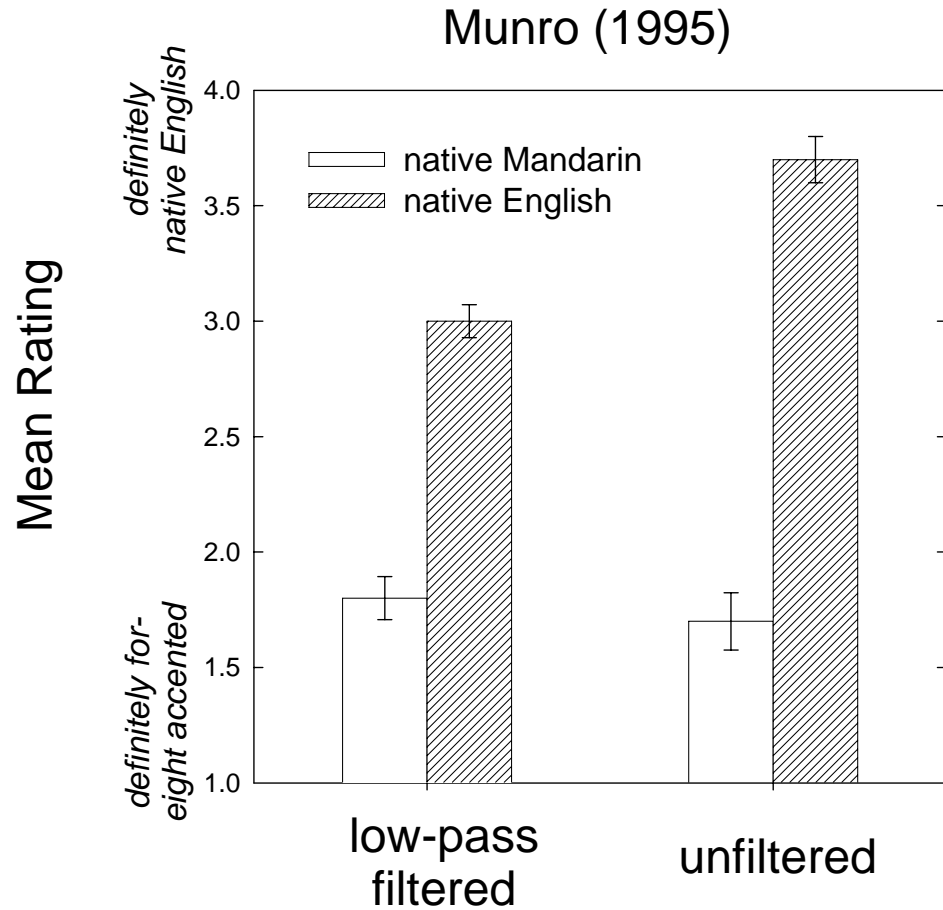


## Munro (1995)

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- English sentences and excerpts of conversational narratives spoken by native speakers of English and Mandarin
- Low-pass filtering (225 or 300 Hz) removed “most” segmental information but left information that specifies prosody (F0, amplitude, duration) intact.
- Materials rated by native English listeners for FA (9- or 4-point scale)

# Munro (1995)



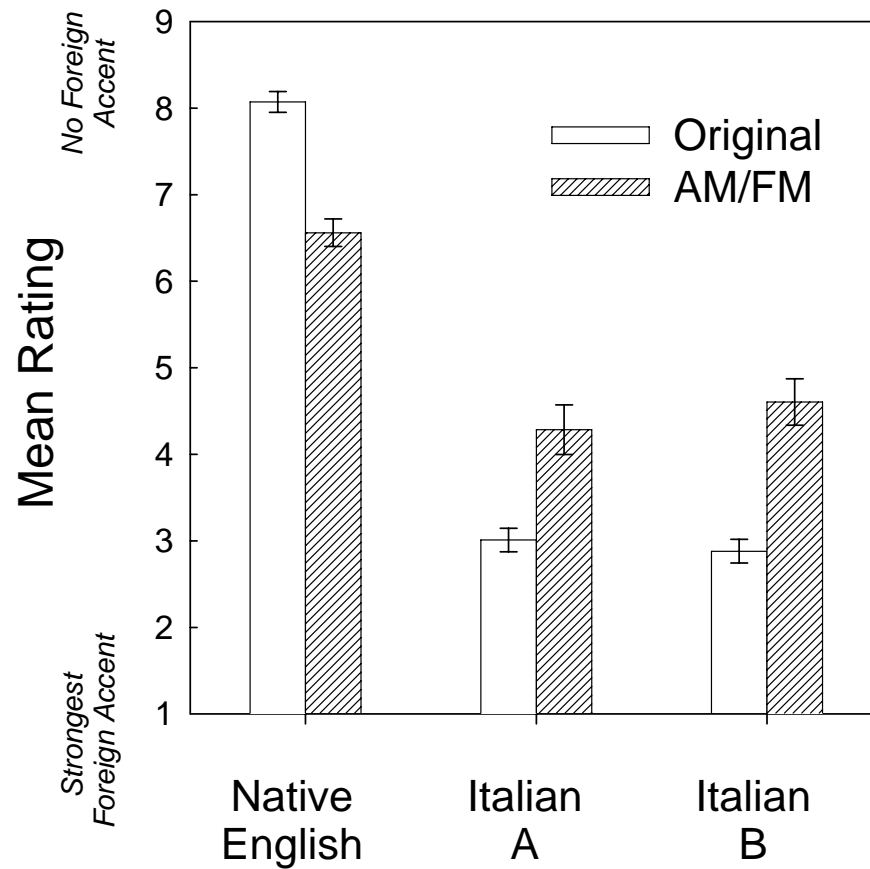
# Sources of FA: prosody



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- Flege & Hillenbrand (unpubl.) examined English sentences produced by native speakers of English and Italian
- Created “hummed” versions of the sentences
  - Amplitude and F0 extracted every 5 ms; used to modulate a schwa vowel.
  - No trace of trace of segmental information in the “AM/FM” sentences
- Original and AM/FM sentences rated by native English listeners for FA

# Flege and Hillenbrand (unpubl.)





# Summary

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- FA arises from L1-L2 differences
- Certain subject factors (e.g., late exposure) contribute to strong FA
- FA is readily detected by listeners, and may lead to negative evaluation or misunderstanding.
- FA may also lead to slowed processing by native listeners

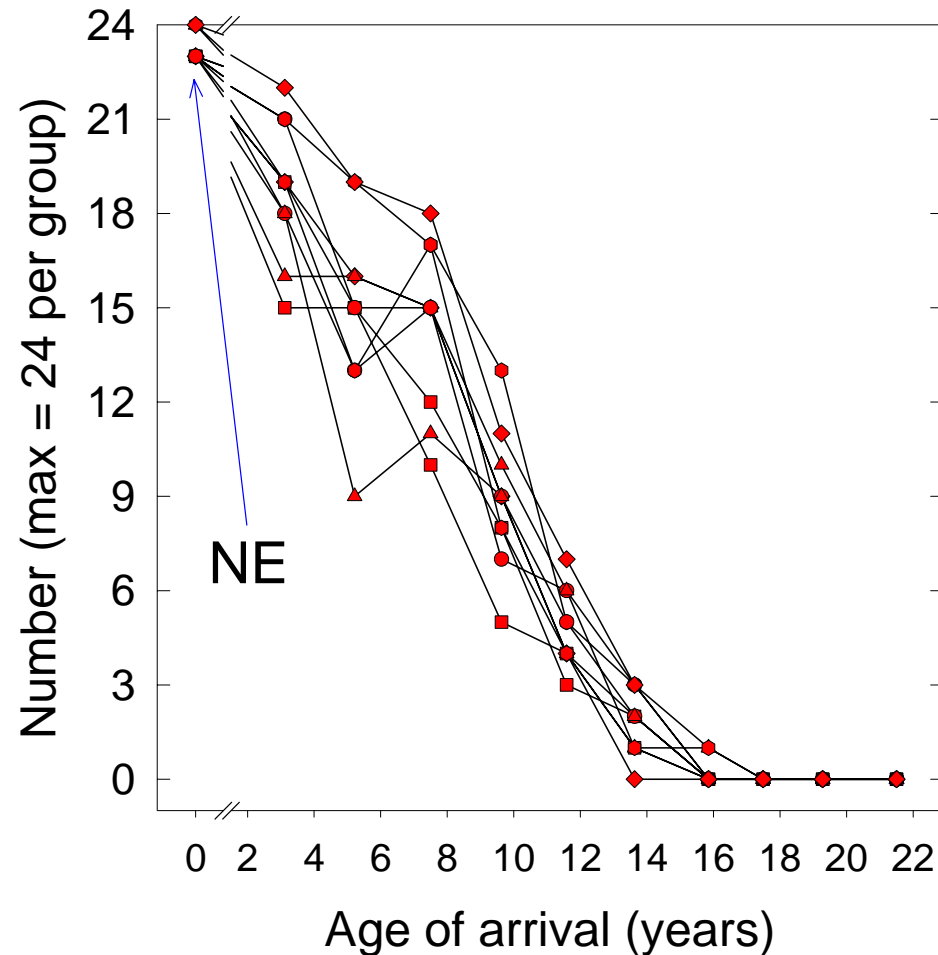


# Summary

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- Both segmental and prosodic errors contribute to FA
- Likely that all auditorily detectable divergences from language-specific phonetic norms are used by listeners in gauging FA
- Uncertain at present what aspects of non-native speech are most responsible for the perception of strong foreign accent or slow processing

# N of participants without a detectable FA (mean ratings within 2 SD of NE mean)



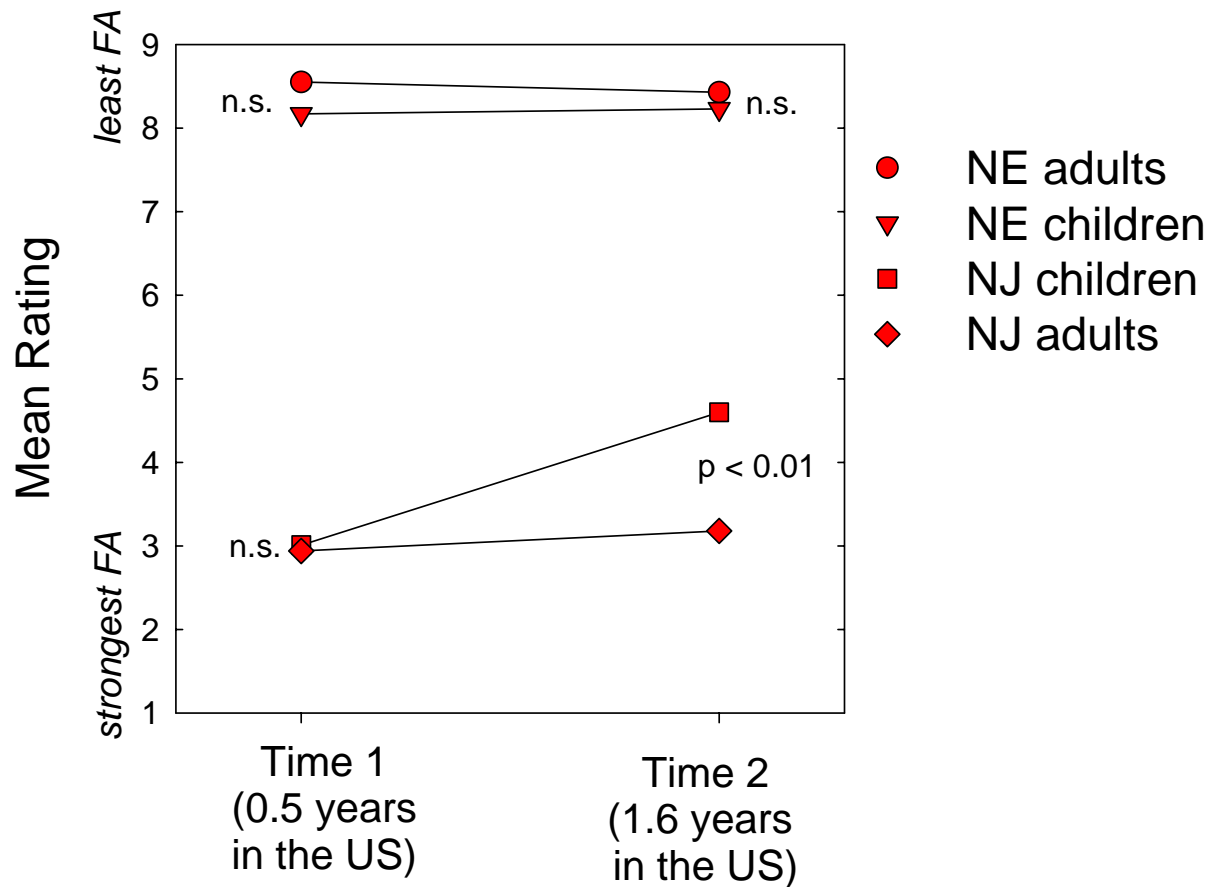
# Aoyama & Flege (unpubl.)



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- Participants: Native English and native Japanese adults (mean age 40 years); NE and NJ children (mean age 10 years)
- Elicit familiar English words (repeated following an aural model & picture)
- Recorded at 2 times, 1 year apart
- Strings of 4-5 words (e.g., “eight neck read six”) presented to 16 NE listeners for overall rating of pronunciation (9-point scale)
- Median ratings examined in both by-talker and by-listener analyses

# Foreign accent results (NJ adults, children)



# Confounds with grammatical error in free-speech samples (Derwing & Munro, 2001)

**Table 1.** Number of listeners' significant correlations of accent features with task scores ( $N = 26$ )

Accent Feature	Accent Rating	Comprehensibility Rating	Intelligibility Score
Grammar score	13 (50%)	14 (54%)	4 (15%)
Phonemic score	4 (15%)	4 (15%)	2 (8%)
Prosodic score	7 (27%)	9 (35%)	2 (8%)
Speaking rate	6 (23%)	10 (38%)	2 (8%)

# Effects of FA: slowed processing

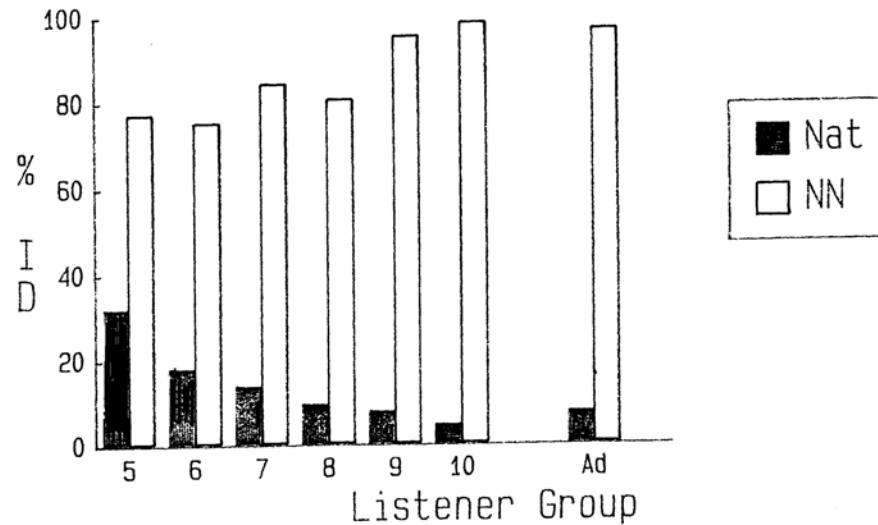


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- Clark (2002) assigned native English listeners to hear unaccented or Spanish-accented renditions of unpredictable SPIN test sentences (e.g., *Ruth must have known about the pie*).
- The final word in each sentence was shown visually immediately after the auditory presentation of each sentence
- Listeners' task: decide if the visual word matched the sentence-final word just heard.
- Responses were significantly longer (ca. 50 ms) for accented than unaccented sentences.

# Scovel (1988)

% Identification as "not American"





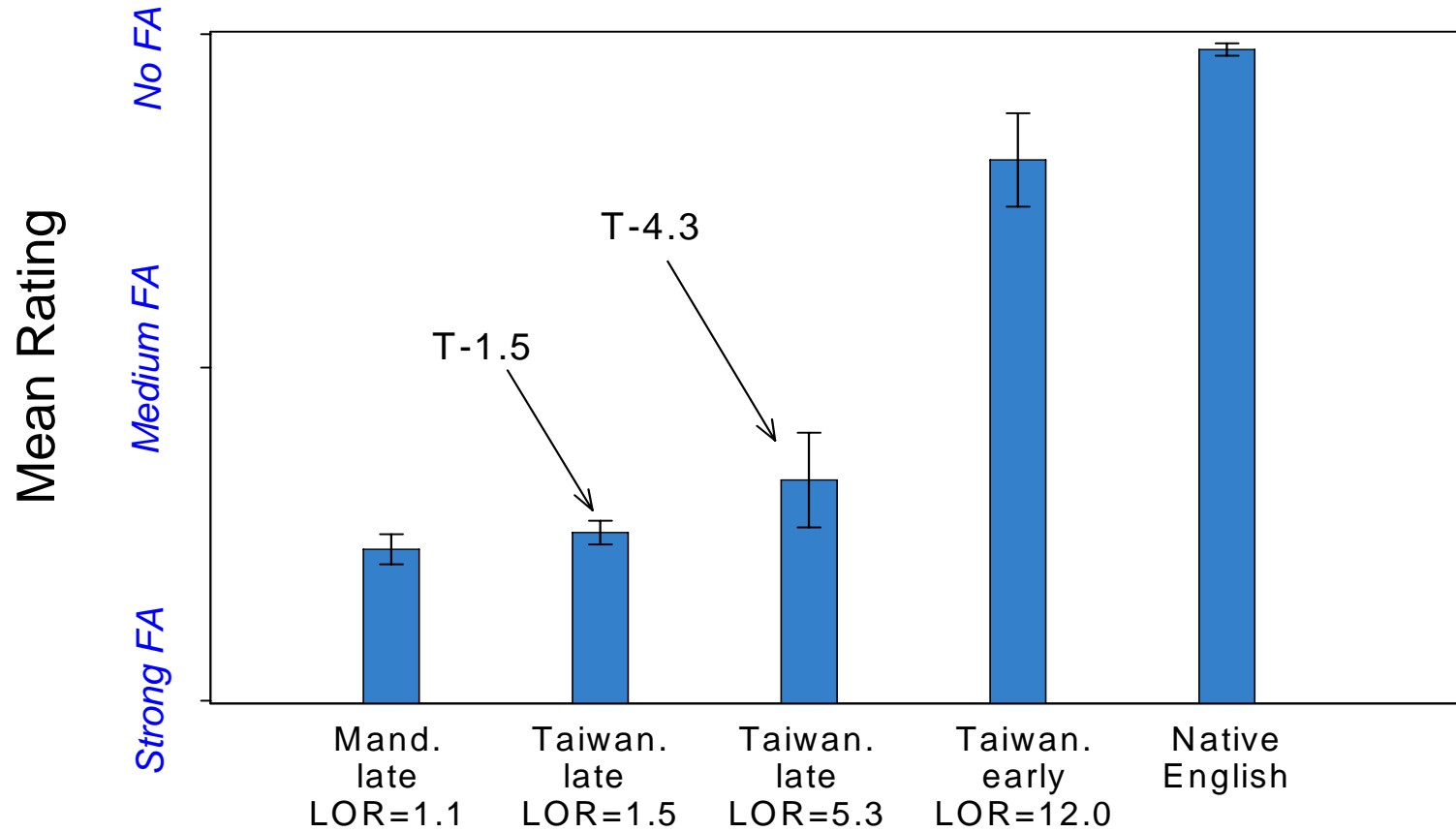
## Flege (1988)

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Native English (NE) listeners rated sentences spoken by NE speakers and 4 groups of Chinese adults. The Chinese participants differed according to

- ❑ age of arrival in the US (children = “early” learners, adults = “late” learners)
- ❑ native variety of Chinese (Taiwanese, Mandarin)
- ❑ length of residence (LOR in the United States)

# Flege (1988)



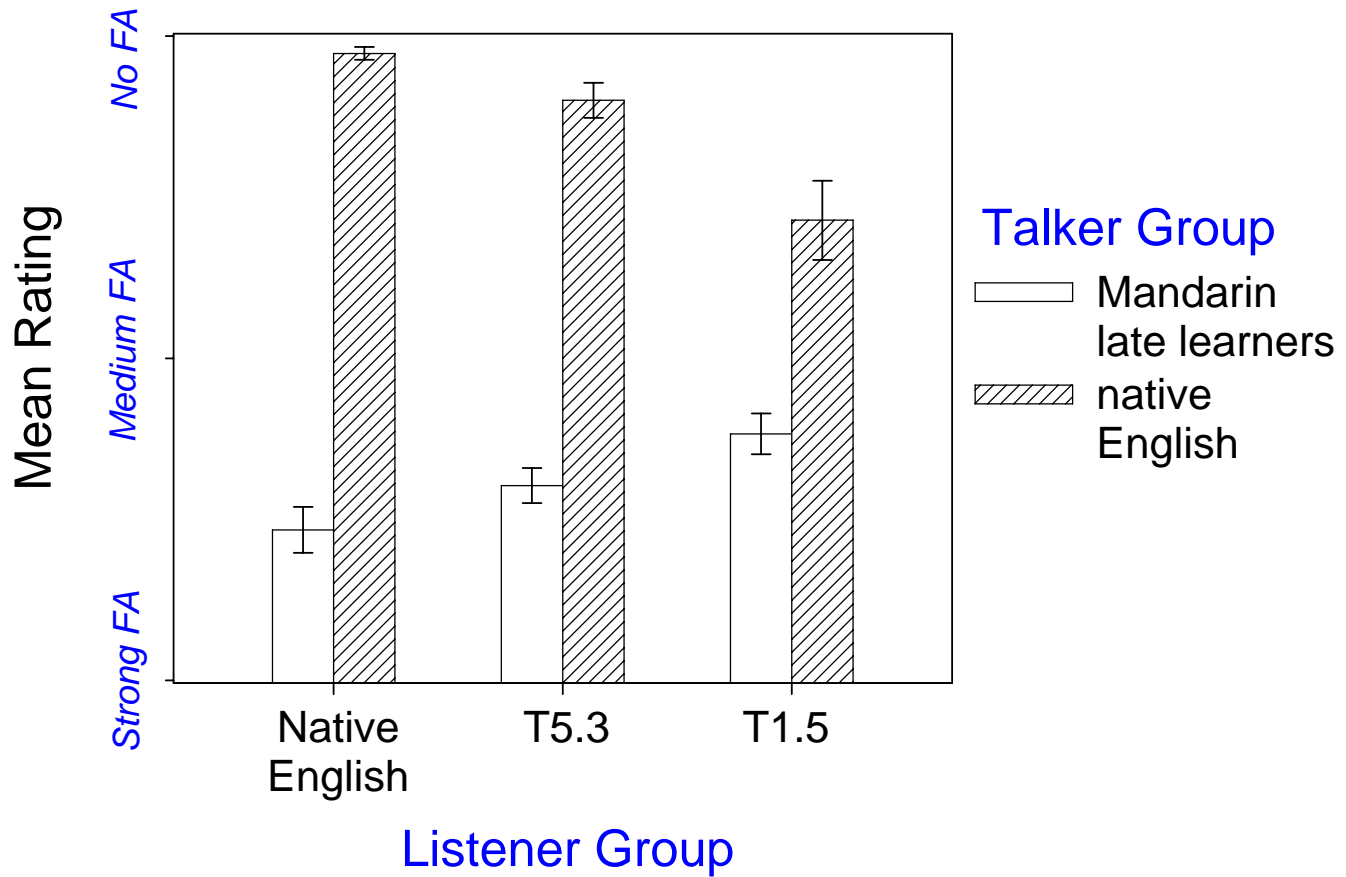


## Flege (1988)

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- Two groups of Taiwanese late learners differing in LOR rated sentences spoken NE speakers and and Mandarin late learners
- Taiwanese listeners less successful in differentiating sentences produced by native English and Mandarin talkers than native English listeners were

# Flege (1988)





# FA in early bilinguals

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- *Due to the passing of a critical period in early childhood?*
  - Unlikely because L1 speech development is still underway
- *Due to interference from the L1?*
  - If so, may vary as a function of amount of L1 use
- *Several studies have shown that amount of L1 use influences degree of FA*

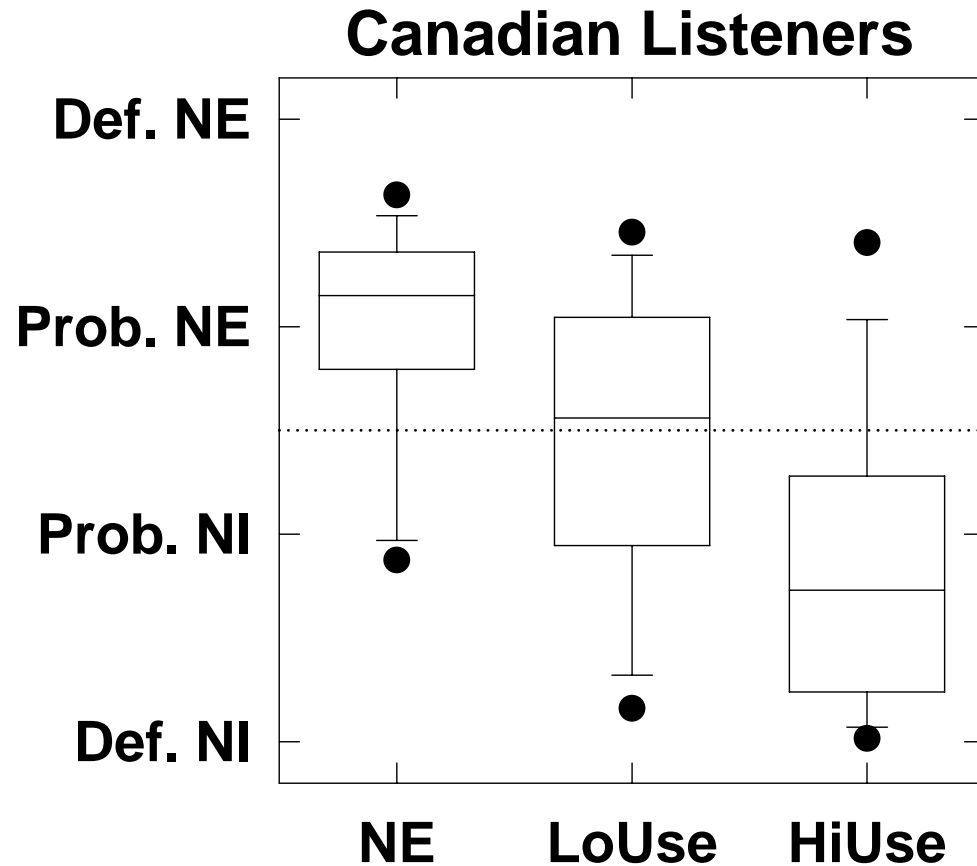
# Effects of L1 use on FA



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- Flege et al. (1997) examined early Italian-English bilinguals who differed according to self-reported % Italian use but were matched for AOA (mean = 7 years).
- Sentences spoken by the early bilinguals and NE controls were classified as having been produced by “native” or “non-native” speaker.

# FA in early bilinguals (Flege et al., 1997)





# Can adults learn speech?

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- Children seem to learn more/faster than adults
- Do adults show improvement over time?
- A number of studies have provided evidence of speech learning by adults
- Examples given for cross-dialect learning (Munro et al., 1999) and L2 learning (Flege, 1988; Flege & Fletcher, 1992)

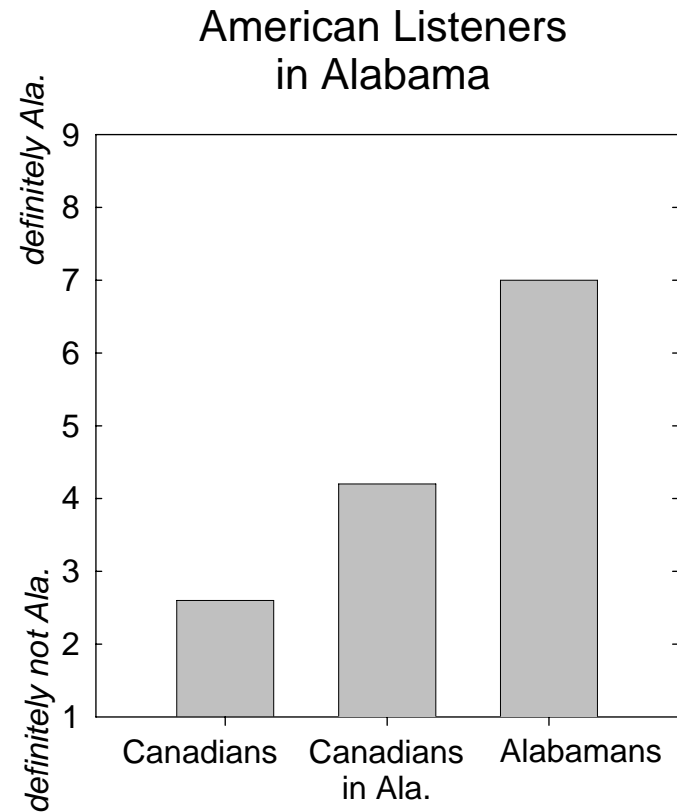
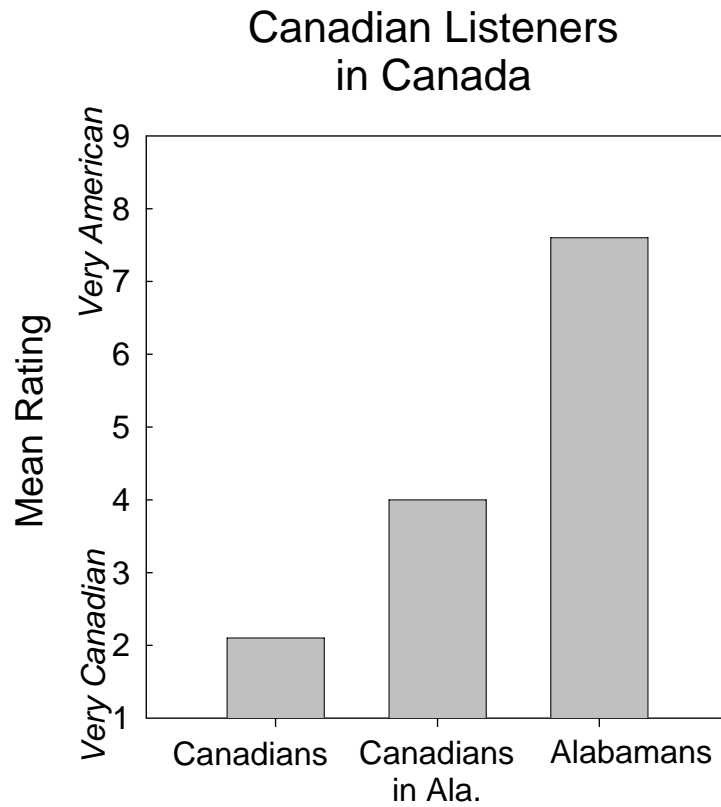


# Can adults learn speech?

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- Munro et al. (1999) recorded three groups
  - Canadians who moved to Alabama
  - Canadians residing in Canada
  - Native Alabamians
- The native dialect (Canadian) and the “foreign” dialect (that of Alabama) differed only phonetically
- The foreign dialect was not a prestige dialect

# Munro, Derwing & Flege (1999)





# Adult L2 speech learning

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Two studies compared degree of FA in groups of adults differing in length of residence in the US

- Flege (1988) compared groups of Chinese adults who had lived in the US for 1.1 and 5.1 years.
- FA of the long-LOR group not significantly better than the shorter-LOR group
- However, a recent study (Flege & Liu, 2001) showed that a 5-year LOR difference was significant only if Chinese immigrants received substantial native-speaker input

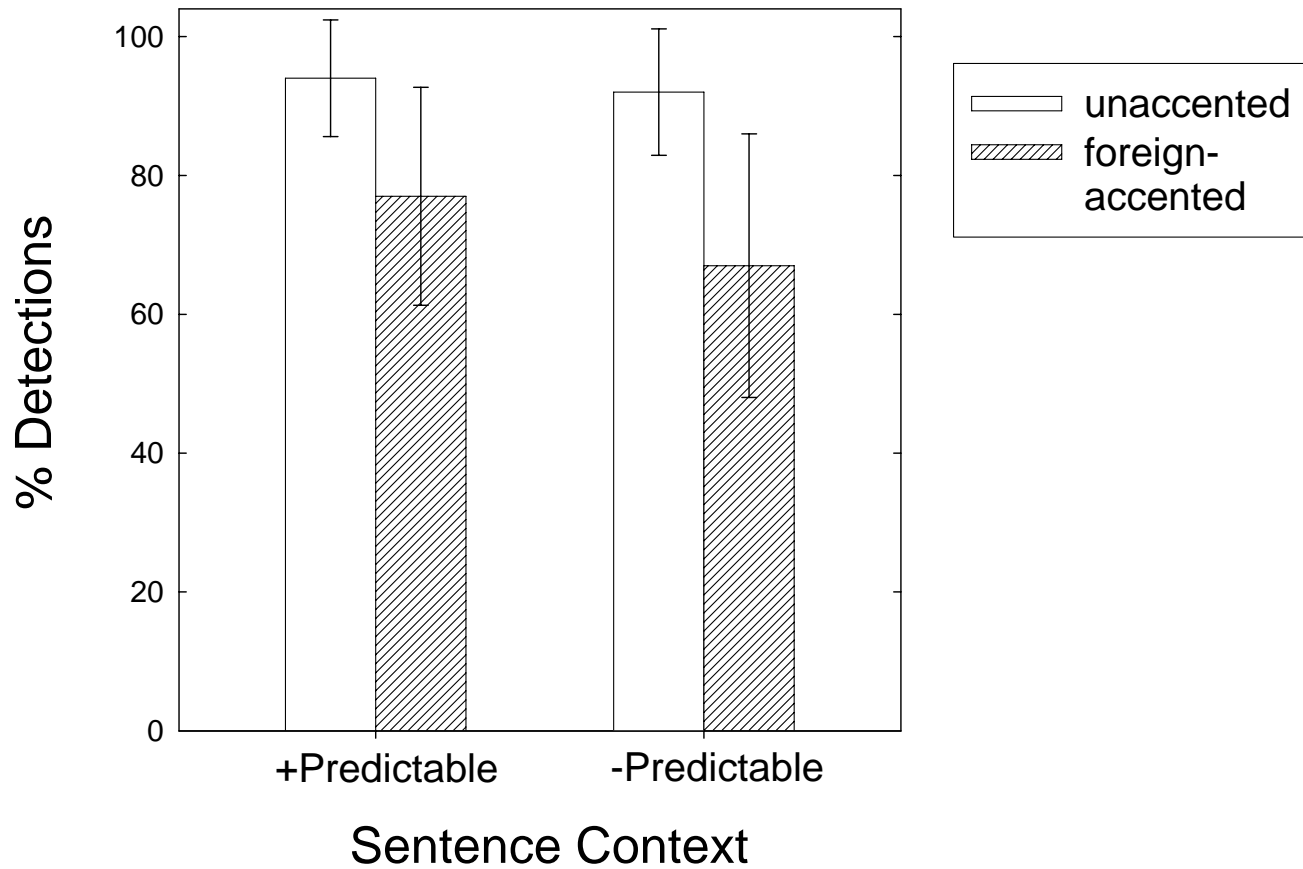


# Adult L2 speech learning

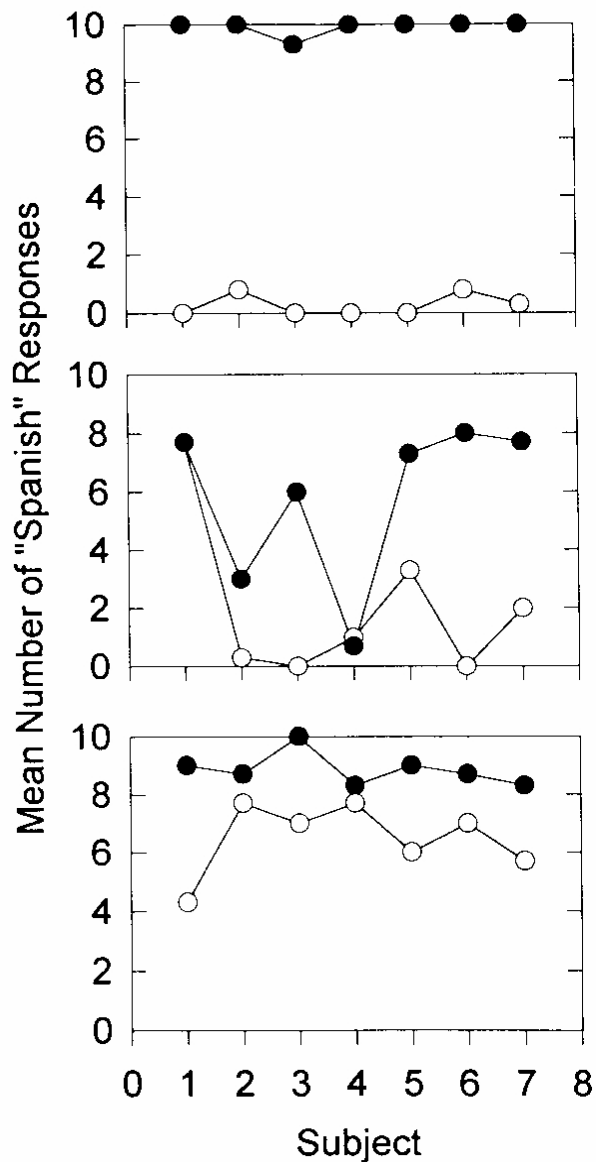
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- Flege & Fletcher (1992) compared groups of native Spanish adults who had lived in the US for average of 0.7 years and 14.3 years
- Long-LOR group had significantly less FA than shorter-LOR group
- More work needed to determine how much/what kind of L2 input needed for improved L2 speech

# Detections of mispronunciations



# % ID as Spanish "taco"

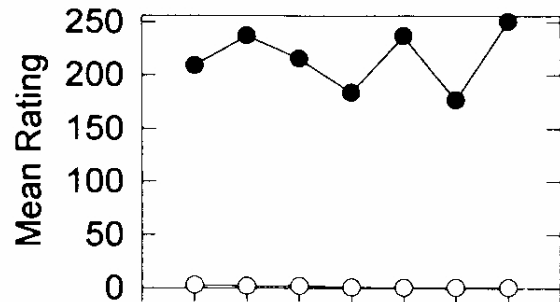


(a) Span. & Eng. mono.

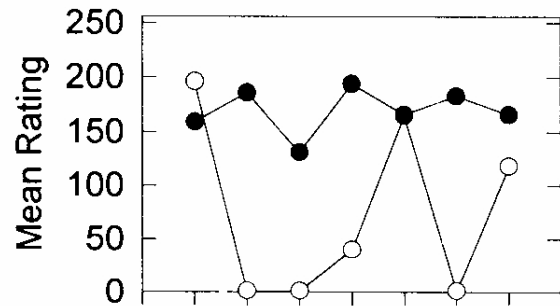
(b) early learners

(c) late learners

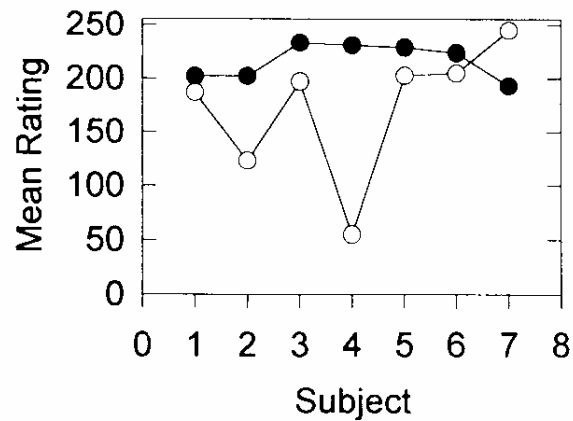
# Mean ratings as Spanish “taco”



(a) Span. & Eng. mono.



(b) early learners



(c) late learners

- Spanish *taco*
- English *taco*

**Table 4.** Summary of forward stepwise regression analyses examining the relation between acoustic variables in *taco* tokens and listeners' perceptual judgments

Step	Variable	Adjusted $R^2$	Change in $R^2$	$F$	$P$
Mean Identification Scores					
1	VOT of /t/	53.6	—	79.77	.000
2	Vowel 2 duration	64.4	10.8	16.91	.000
3	F2 Vowel 1	68.1	3.7	6.63	.017
4	F2 onset Vowel 2	70.4	2.3	4.43	.047
5	VOT of /t/ REMOVED	—	—	—	—
6	F1 Vowel 1	73.2	2.8	4.19	.053
7	F3 (onset) of Vowel 2	77.8	4.6	6.81	.016
8	F3 (offset) of Vowel 2	80.6	2.8	4.30	.049
Mean Ratings					
1	VOT of /t/	86.6	—	870.45	.000
2	VOT of /k/	89.6	3.0	33.09	.000
3	F3 of Vowel 1	90.9	1.3	14.63	.001
4	F2 (onset) of Vowel 2	92.6	1.7	17.68	.000
5	F1 (offset) of Vowel 2	95.2	2.6	24.00	.000
6	Vowel 2 intensity	96.8	1.6	14.81	.001
7	Vowel 2 duration	97.2	0.4	3.98	.059

**Note:** The  $F$  values are tests of significant  $R^2$  changes using the error term from the final step of the analyses.



# Explanations for Age Effects

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1. *Maturation constraint*: the capacity for learning speech is reduced as the result of normal neural maturation (e.g., Scovel, (1981, 1988).
2. *Input*: children receive more native-speaker input than adults do
3. *Motivation*: Children are more strongly motivated to learn to pronounce the L2 accurately because they want to “fit in” with their peers.



# Explanations for Age Effects

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4. *L1 development-A*: Native language production patterns are better established in adults than children, and so are more likely to be maintained in L2 production
5. *L1 development-B*: Native language perception patterns are better established in adults than children, leading to a greater likelihood of misperception (which, in turn leads to production errors)