The **critical period hypothesis** for language acquisition

1) an empirical claim: There is a limited period, in the first years of life, during which humans can acquire a language to a native-like level of proficiency.

2) a theory: The neural substrate required for language learning “loses plasticity” with maturation.

Penfield & Roberts (1959) *Speech and Brain mechanisms.*

Lenneberg (1967) *The Biological Fundations of Language.*

“Language acquisition circuitry is not needed once it has been used. It should be dismantled if keeping it around incurs any cost [...] Greedy neural tissue lying around beyond its point of usefulness is a good candidate for the recycling bin.”

Pinker, 1994, *The Language Instinct.*

Note that there several possible explanations:
- maturationnal constraints (“loss of plasiticity”)
- “use it then lose it”
- “use it or lose it” (Tom Bever)

Critical Periodes in Animals

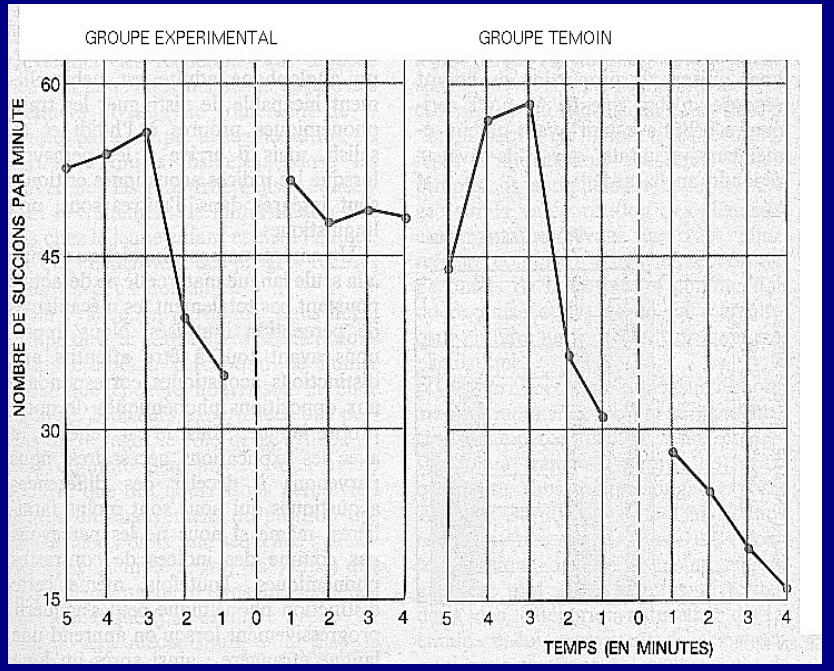
- Effect of visual deprivation on ocular dominance
  - Hubel & Wiesel (1965) Comparison of the effects of unilateral and bilateral eye closure on cortical unit responses in kittens. *J Neurophysiology.*
- Song learning in sparrows
  - Marler & Peters (2010) A Sensitive Period for Song Acquisition in the Song Sparrow, Melospiza melodia: A Case of Age-limited Learning. *Ethology*
- Plasticity of auditory space map:
  - Knudsen EI, Knudsen PF (1990) Sensitive and critical periods for visual calibration of sound localization by barn owls. *J Neurosci.*

Knudsen and Knudsen, 1990

- **Owls** equipped with *prismatic spectacles* within first month of life exhibited large adaptive shifts auditory orienting behavior, whereas owls equipp with prisms as adults did not.
- The capacity of abnormal vision to alter sound localization declined to adult levels by 70–100 d of age.
- The restoration of normal vision to owls that were raised wearing prisms led to full recovery of accurate sound localization in animals younger than 200 d old, an age that just precedes sexual maturation.
- In contrast, owls that continued to view the world through prisms until adulthood failed to recover accurate sound localization after prism removal.

Evidence for Critical period in language acquisition

- In the first years of life, spoken (or sign) language acquisition is “quasi spontaneous”, compared to other many other skills.
- Lots of research showing a lot of learning of phonological features of language in the first year of life.
- Children typically recover better from aphasia than adults (Lenneberg; other ref?)
- Debate: Specialized mechanisms or not? At a minimum, there is a tropism for language.



Effect of age of acquisition on **the first language**

- Cases of abandonned or abused children (Gaspard Hauser, Victor de l'Aveyron (Isard), Genie (Curtiss))
- Deaf users of sign language (see, e.g., Mayberry & Eichen 1989; Newport, 1990)

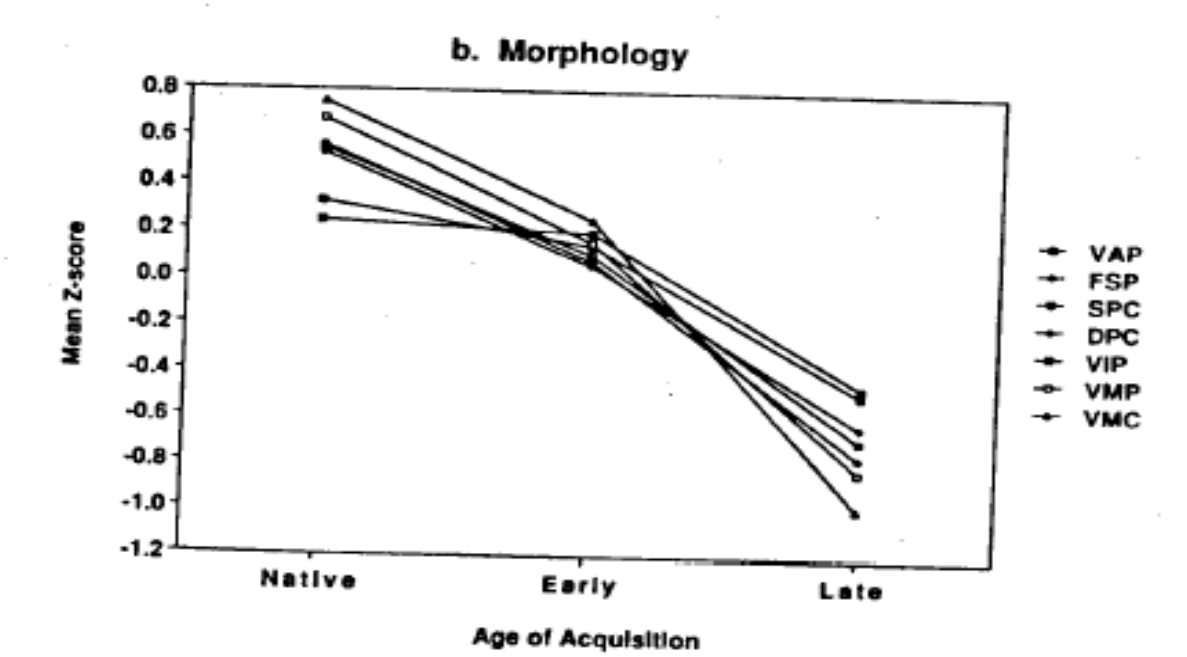
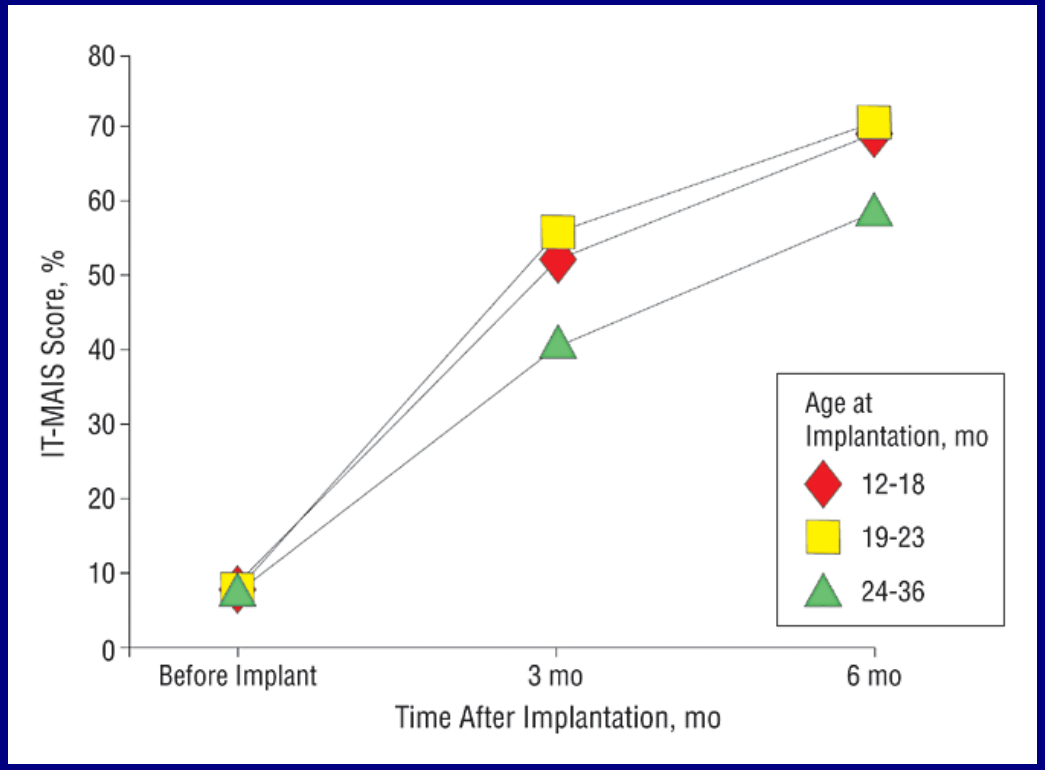


Figure 1b. Z-scores on 7 tests of ASL morphology for Native, Early, and Late Learners of ASL.

Effect of age of cochlear implantation on auditory skills

- Data from 117 congenitally-deaf children who received the implants.



(McConkey Robins et al, (2004). Arch. Otolaryngology.)

CP is the outcome of **deprivation** of language in the first years of life

(Mayberry, Lock & Kazmi (2002). *Nature)*

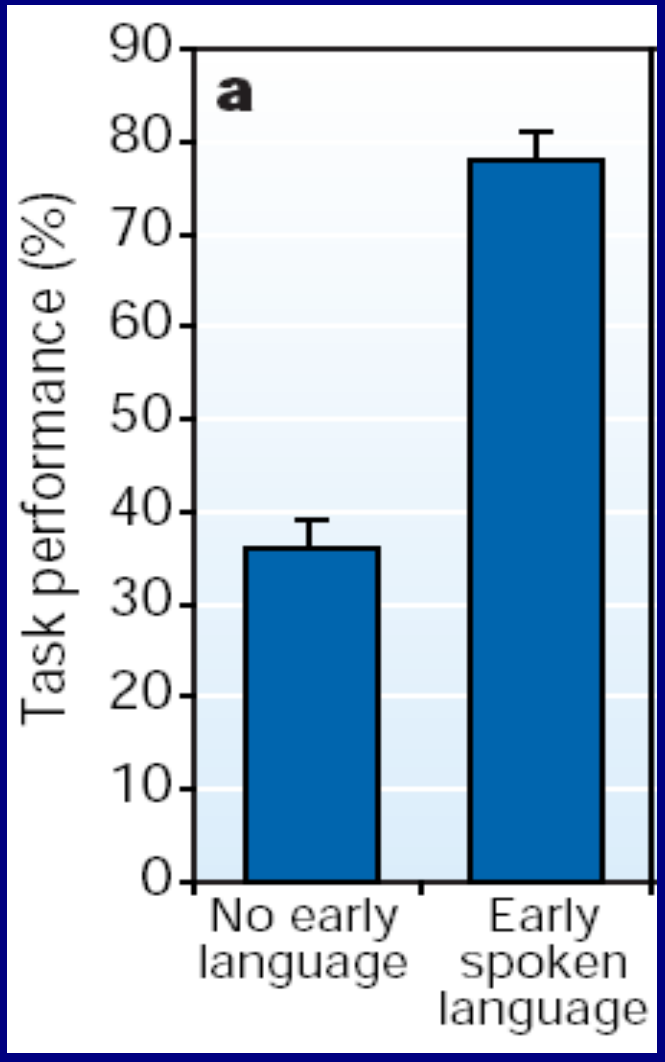
Comparison of two groups of adults who learned ASL between 9 and 15 years of age:

1. adults born deaf
2. adults born hearing who had learned English before becoming deaf.

Task: ASL sentence recall

Conclusion: "Individuals who are born deaf and isolated from language during early childhood grow up being linguistically dysfunctional"

[Note that proficiency in ASL is not simply related to age of acquisition. A purely maturational CP cannot explain these results.]

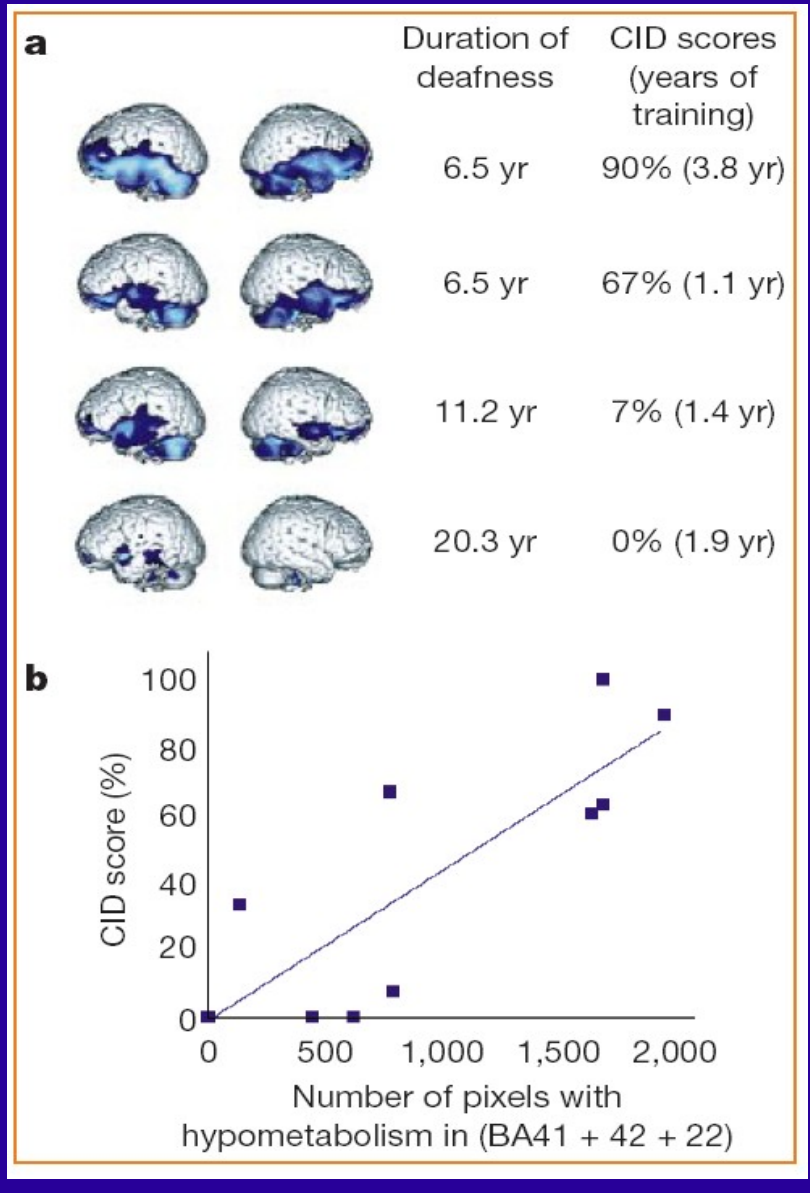


Maybe neural recruitment prevents delayed language acquisition

(Lee et al, *Nature*, 2001)

- Measurements of glucose metabolism in deaf subjects *before cochlear implementation*

- The intelligibility scores correlated with *hypometabolism* in language regions.



There is also an effect of age of acquisition for second language (L2)

Effect of age of acquisition on foreign accent in a second language.

Goodness ratings of immigrants' accents decrease with age of immigration (Flege, Munro & MacKay, *JASA*, 1995)

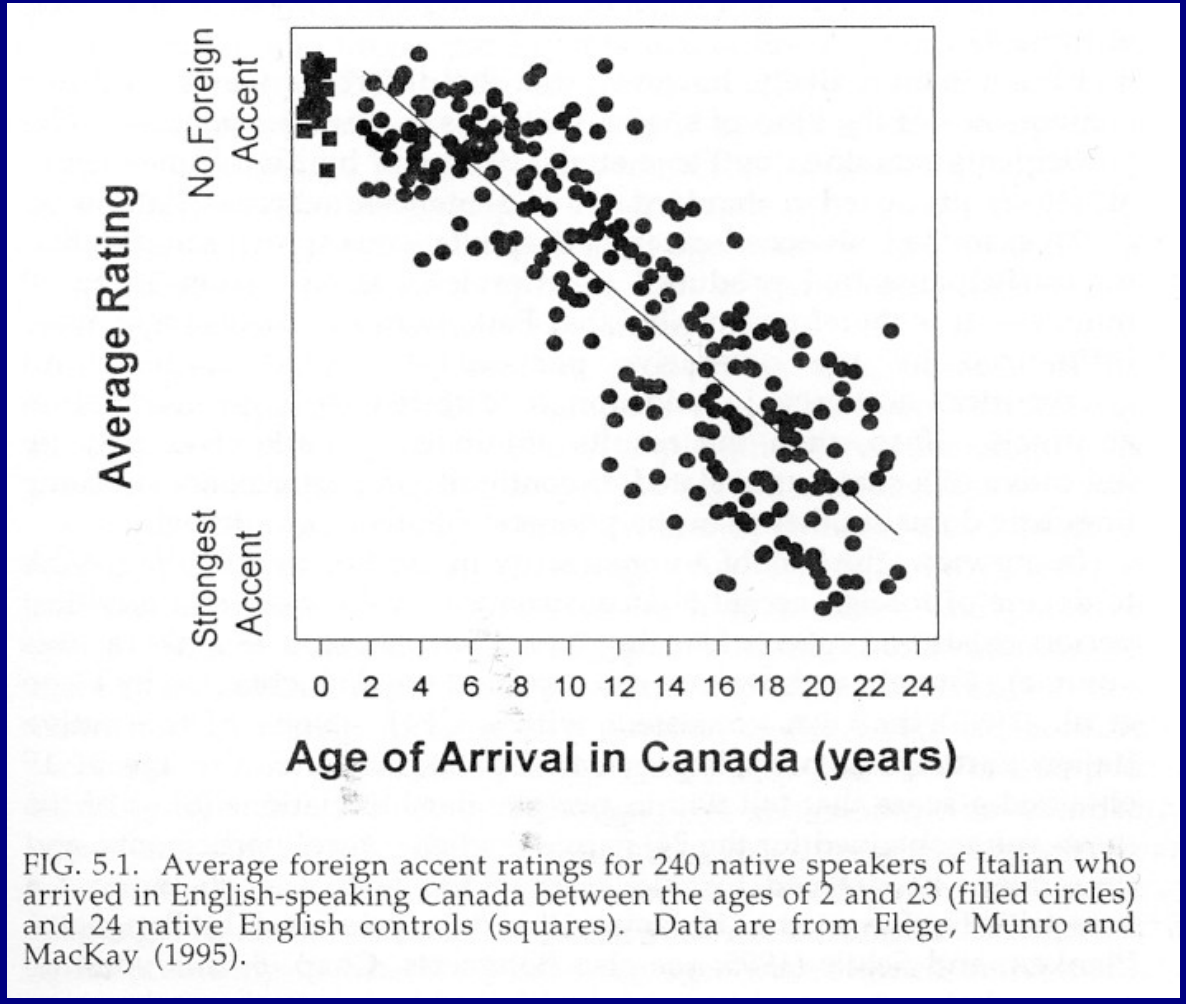


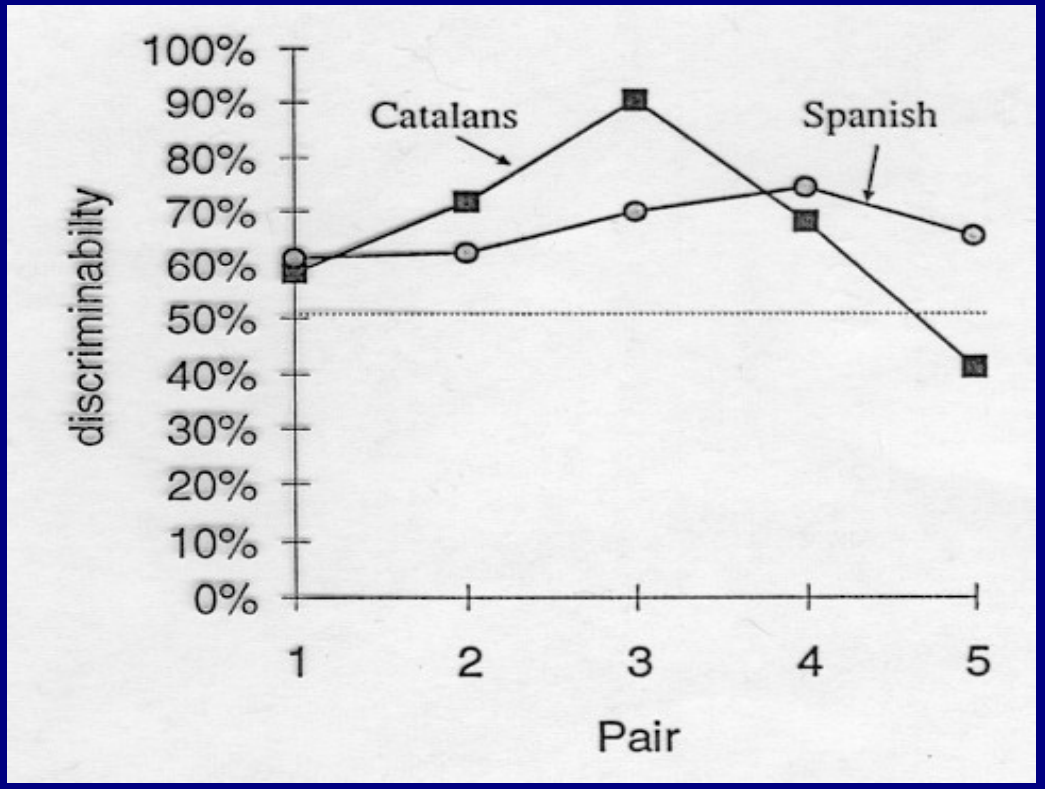
FIG. 5.1. Average foreign accent ratings for 240 native speakers of Italian who arrived in English-speaking Canada between the ages of 2 and 23 (filled circles) and 24 native English controls (squares). Data are from Flege, Munro and MacKay (1995).

Difficulties in L2 speech perception.

Even when they have been intensively exposed to Catalan since the age 4~6, native speakers of Spanish still have difficulties perceiving the differences between some Catalan phonemes ([ɛ] vs. [e], [s] vs. [z]...)

Discrimination of pairs of synthetic vowels along a continuum ranging from the

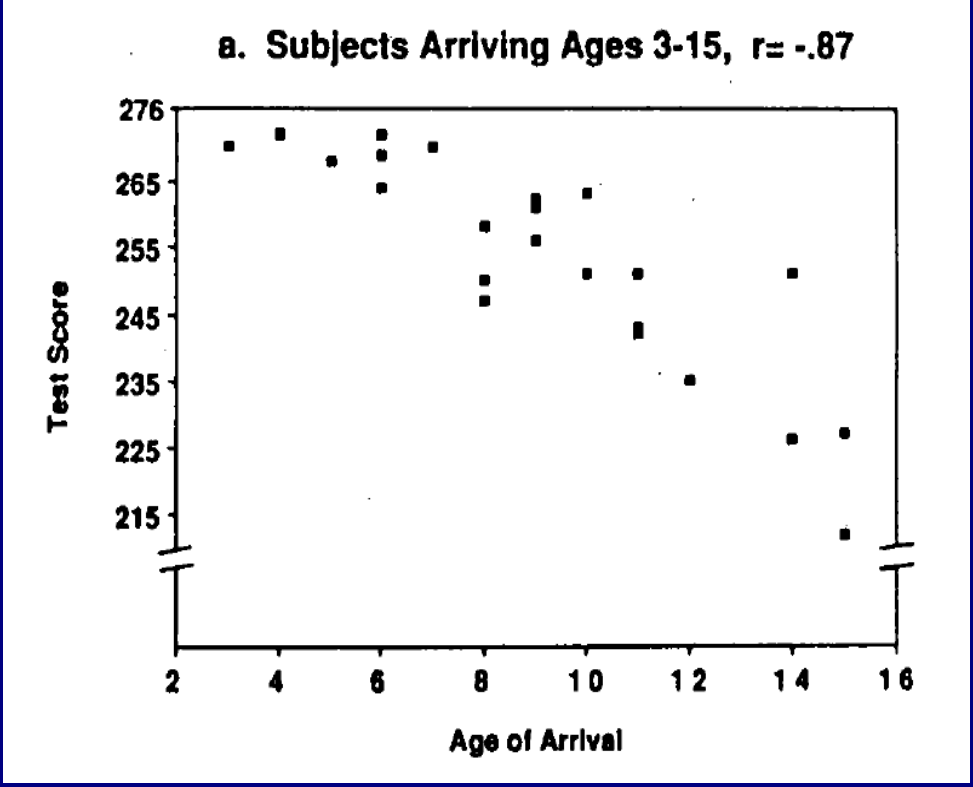
Catalan vowel “ɛ” to the Catalan vowel “e”.



(Pallier, Bosch & Sebastian-Galles, *Cognition*, 1997, *Psych. Sci.* 2001)

Effect of age on syntax

- Scores on tests of English grammar in relation to age of arrival in the US of Korean immigrants (Johnson & Newport, 1989, see also Flege, Birdsong, Neville, ...)



ERPs evidence for age acquisition effects (Weber-Fox & Neville (1996). J. Cogn. Neurosci)

- Participants: 61 adult Chinese/English bilinguals, exposed to English at different points in development: 1–3, 4–6, 7–10, 11–13, and after 16 years of age.

- Task: reading sentences with semantic anomalies or different types of syntactic violations.

Table 2. Examples of Control (C) and Violation (V) Sentences[a]

Semantic/pragmatic control and violation:

C#1. The scientist criticized Max's *proof* of the theorem.

V#1. The scientist criticized Max's *event* of the theorem.

Phrase structure control and violation:

C#2. The scientist criticized a proof *of* the theorem.

V#2. The scientist criticized Max's *of* proof the theorem.

Specificity constraint controls and violation:

C#1. The scientist criticized Max's *proof* of the theorem.

C#3. What did the scientist criticize a *proof* of?

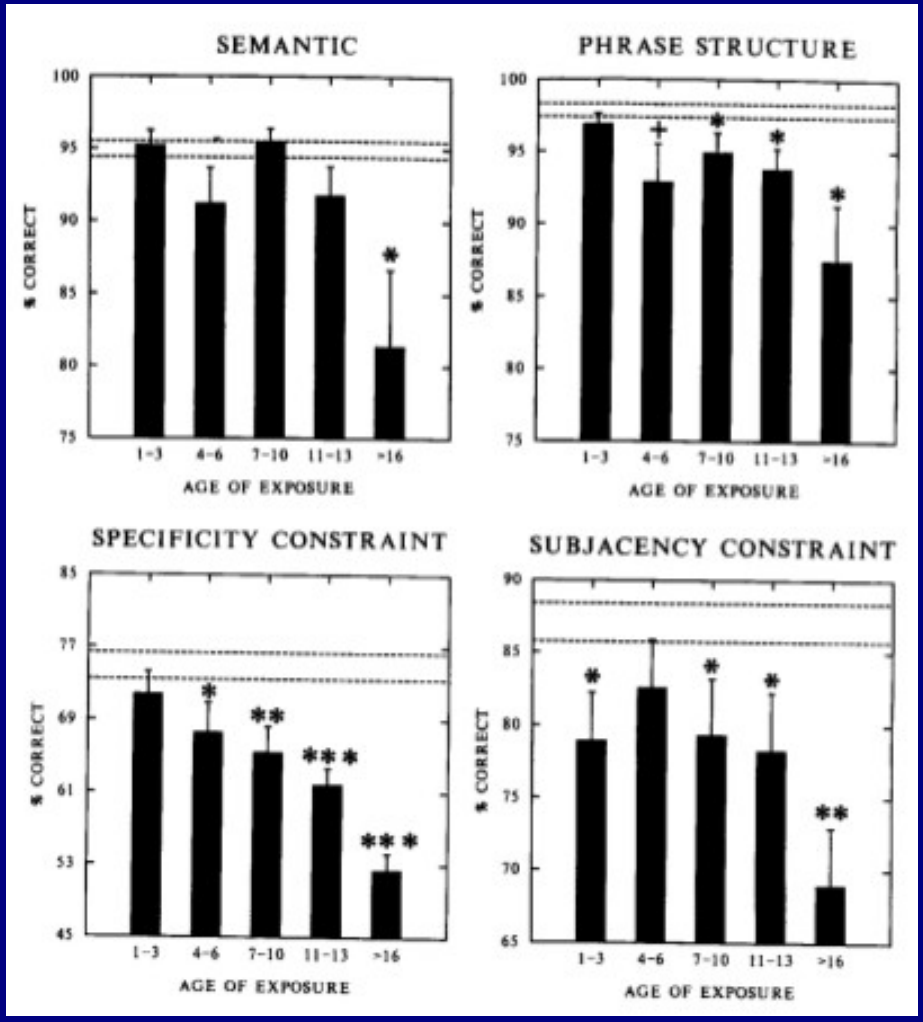
V#3. What did the scientist criticize Max's *proof* of?

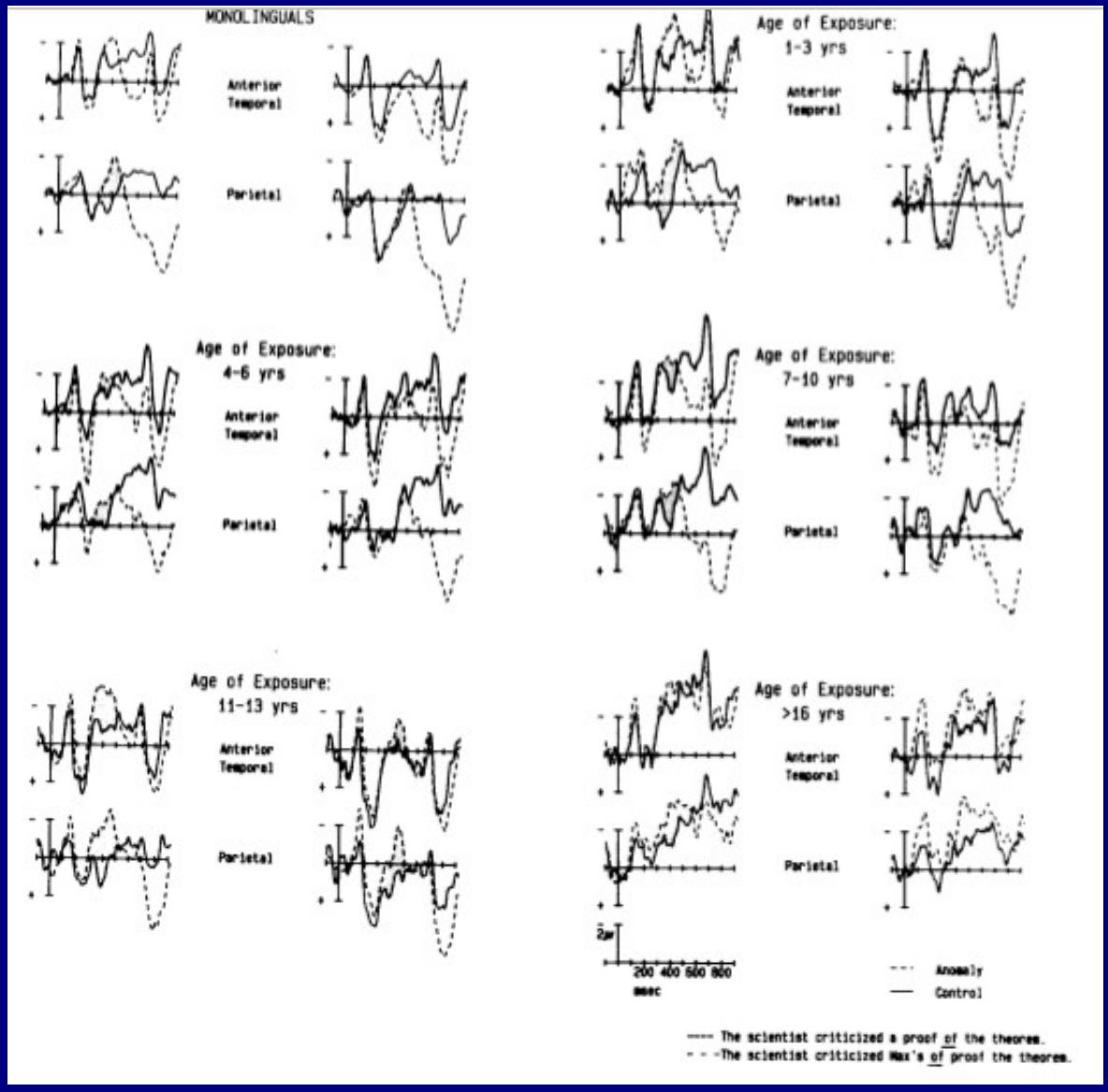
Subjacency constraint control and violation:

C#4. Was the proof of the theorem *criticized* by the scientist?

V#4. What was a proof of *criticized* by the scientist?

[a] Italicized words indicate comparison points for control and violation sentences.



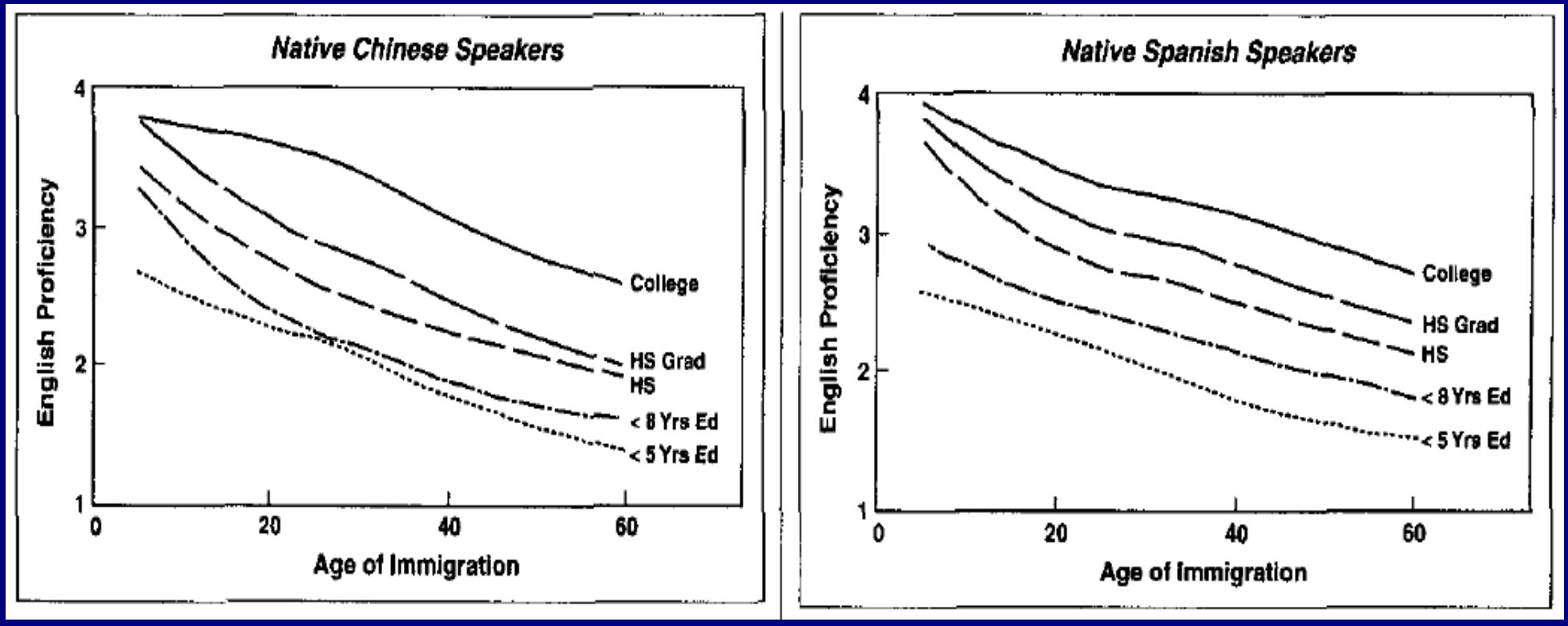


Results:

- syntactic anomalies: differences with natives are observed in all L2 Ss
- semantic anomalies: only the older ones show differences.

Remark 1: A steady decline across the life-span

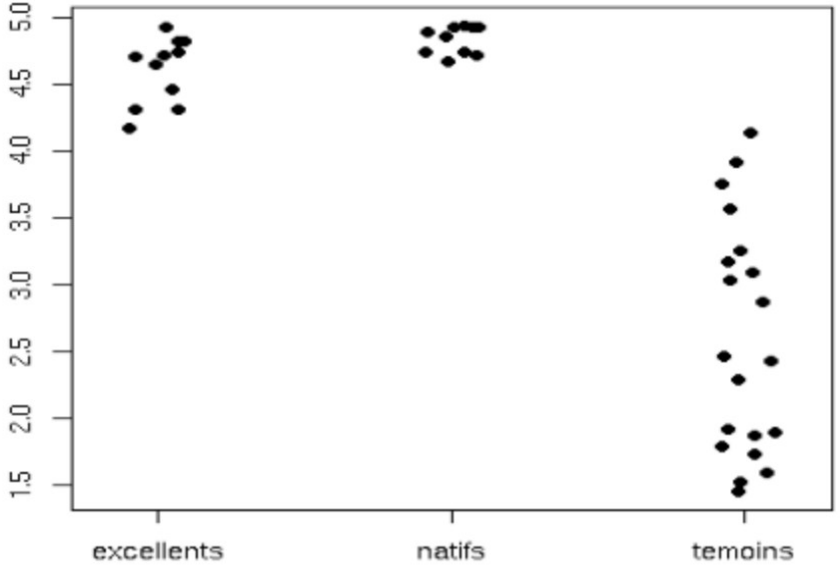
- Hakuta, Bialystok & Wiley (2003) used data from the 1990 US census to plot the *self-rated proficiency* of 2.3 millions immigrants (on a scale from 1 to 5):



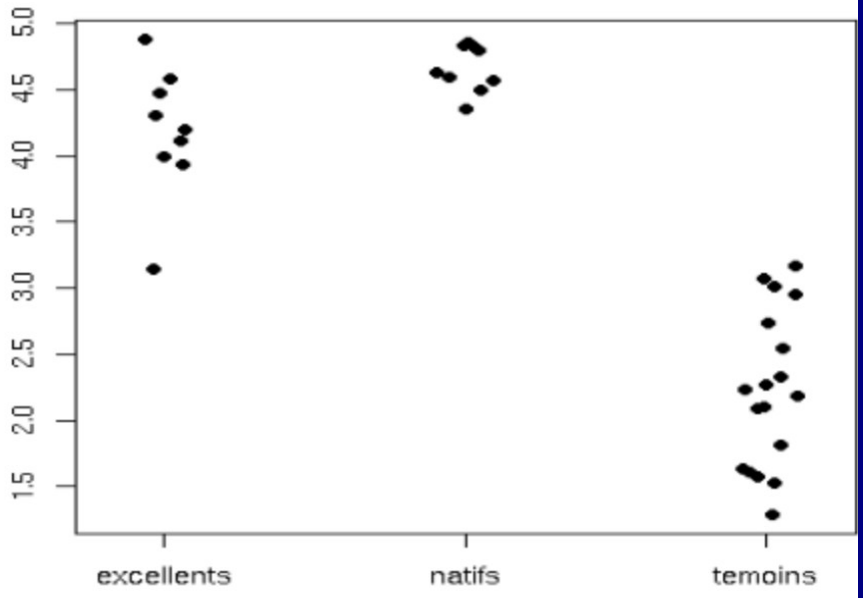
Remark 2: some individuals seem to reach native-like proficiency.

Bongaerts (1999) studied Dutch learners of English or French, who started to learn L2 in high-school (after 12 years of age). Their accents were rated by native English & French speakers.

English



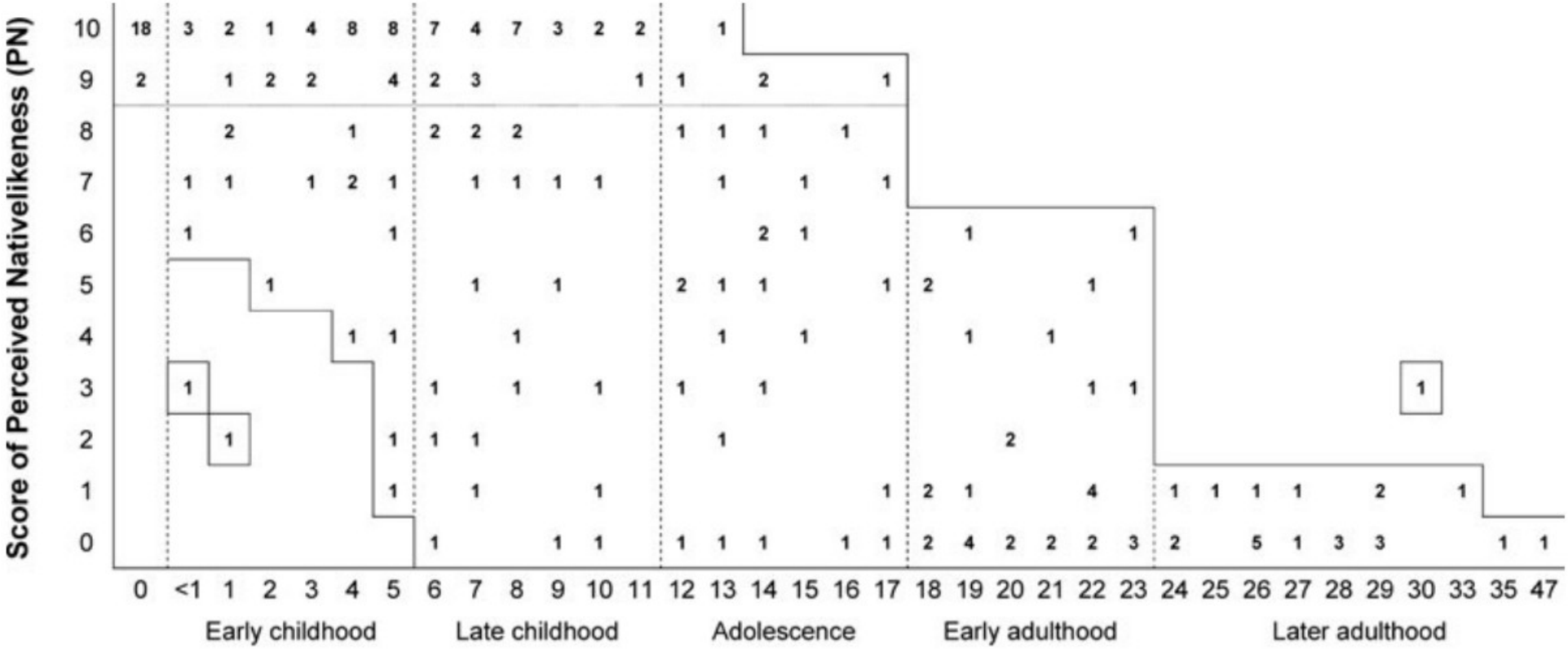
French



The Swedish mega-study of Abrahamson & Hyltenstam

(2009, *Language Learning*)

- Participants: 195 native Spanish speakers, migrants in Sweden, who self rate their accent as excellent in their L2 Swedish (AOA of L2 between 1 and 47 years).
    - Evaluation of their accents by native Swedish judges



Battery of 10 tasks ran on the “best”

Participants: 41 speakers who passed for native speakers for at least 6 judges out of 10.

Tasks:

- - Speech production/perception
- - Grammatical judgments (GJT)
- - Cloze test, Idioms, Proverbs
-
- Result: Only 3 participants (/41) scored in the native ranges in the 10 tasks (AOA: 3, 7, 8).
-
- Conclusions: 1/ after 11y, proba nativelikeness = 0. 2/ even early L2 acquisition does not ensure ultimate native-likeness

Table 9 The rate of nativelike attainment within different linguistic domains; the ten instruments rank-ordered per AO group

Percent of participants within NS range	AO 1–11 ($n = 31$)	AO 13–19 ($n = 10$)
94%	RTs (GJT, auditory)	
74%	VOT production	
71%	VOT categorical perception	
68%	Word percentage in babble noise	
65%	GJT (written)	
60%		RTs (GJT, auditory)
58%	GJT (auditory)	
58%	Idioms	
52%	Cloze test (grammar/semantics)	
50%		GJT (written)
50%		GJT (auditory)
50%		Cloze test (gramm./sem.)
48%	Sentence percentage in white noise	
40%		VOT production
30%		Word percentage in babble noise
30%		Sentence percentage in white noise
20%		Idioms
20%		VOT categorical perception
16%	Proverbs	
10%		Proverbs

Remark

- Studies showing an effect of age on L2 ultimate attaintment were mostly performed on children in naturalistic, immersive, conditions (immigrants).
- Not clear at all whether this applies to exposure to L2 in schools.

- David Birdsong (1999) *Second language acquisition and the critical period hypothesis*

- David Singleton & Lisa Ryan *(2004) Language Acquisition: The Age Factor (2nd Edition)*

Interpretation of the age effect on L2 acquisition

The AOA effect on L2 proficiency is often interpreted in the framework of the critical period hypothesis: It is supposed to reflect a progressive, irreversible, maturational loss of plasticity of the neural circuits for language.

An alternative possibility: interference from L1

- While learning L1, the connections in neural networks that subserve language may progressively stabilize. The later the exposure to L2 starts, the less the system can “perturbed”.

- Unlike in the CP hypothesis, the circuits for language do not necessarily **irreversibly** lose plasticity. It is the active use of L1 that prevents “perfect” L2 acquisition.

Studying language attrition

What happens to people who have stopped using their first language and exclusively use a second language?

If the language areas in the brain have started to "crystallize" during L1 acquisition, then one may expect:

(a) to find traces left by early exposure to L1

(b) that L2 may be processed in a non-nativelike manner.

Studies on foreign adoptees

Participants:

young adults (mean age=30 yrs) of Korean origin adopted by French families at ages ranging from 3 yrs to 10 yrs (mean=6.5 yrs).

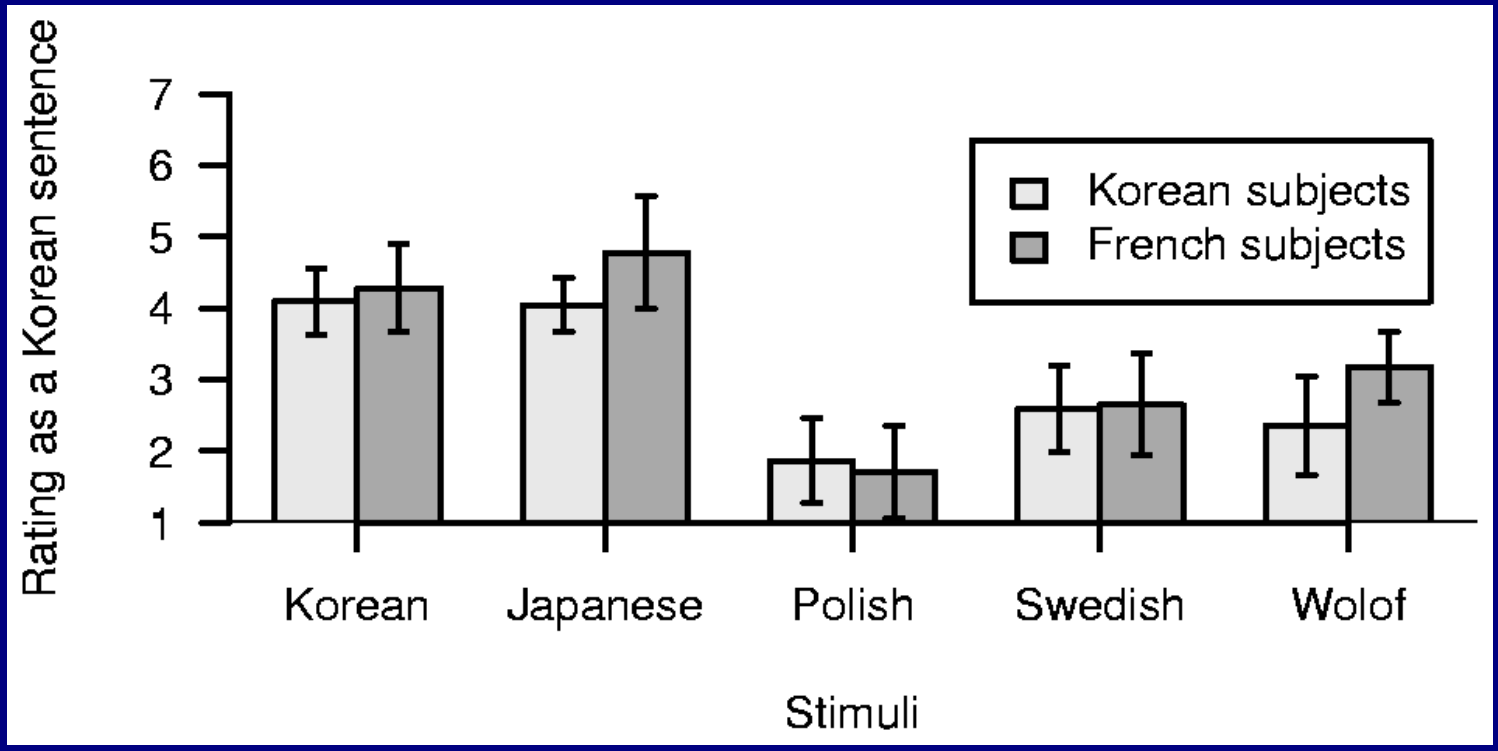
Control groups:

- monolingual French speakers, matched in age and gender.

- in some experiments, Korean speakers who live in France and have been using French for 2 to 7 years.

Recognition of Korean sentences

Sentences from 5 languages (3~4 seconds long) were presented and participants gave confidence ratings for each sentence is Korean (ratings: 7=sure it is, 4=unsure, 1=sure it is not).



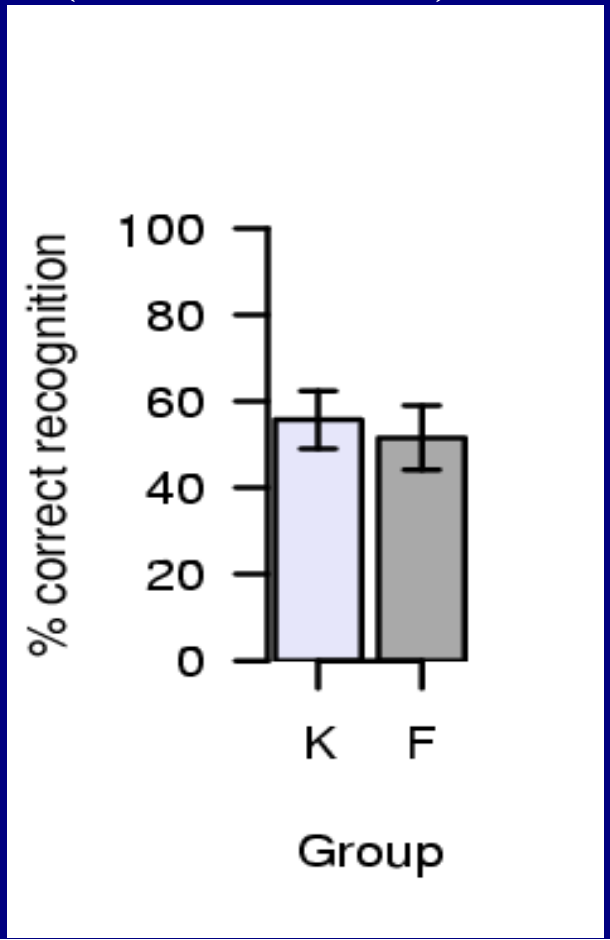
(Pallier et al., 2003, *Cerebral Cortex*)

Word identification

In a series of trials, participants had to select among two Korean words presented auditorily which was the translation of a given French word. The relevant measure is the percentage of correct responses (chance=50%).

Koreans participants did not perform better than french controls.

None had a score exceeding chance level (at $p<.05$)

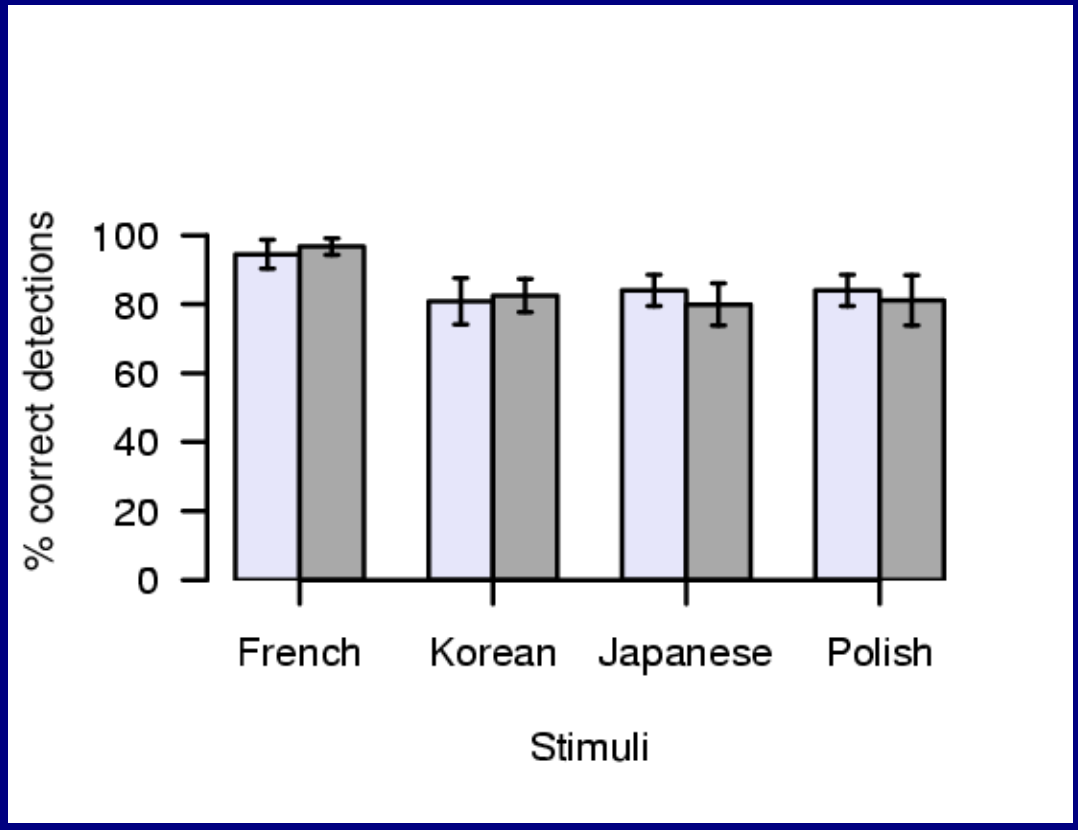


Brain imaging using event-related fMRI

Adoptees and French Ss were scanned while listening to sentences in French, Korean, Japanese and Polish (3 female speakers/language).

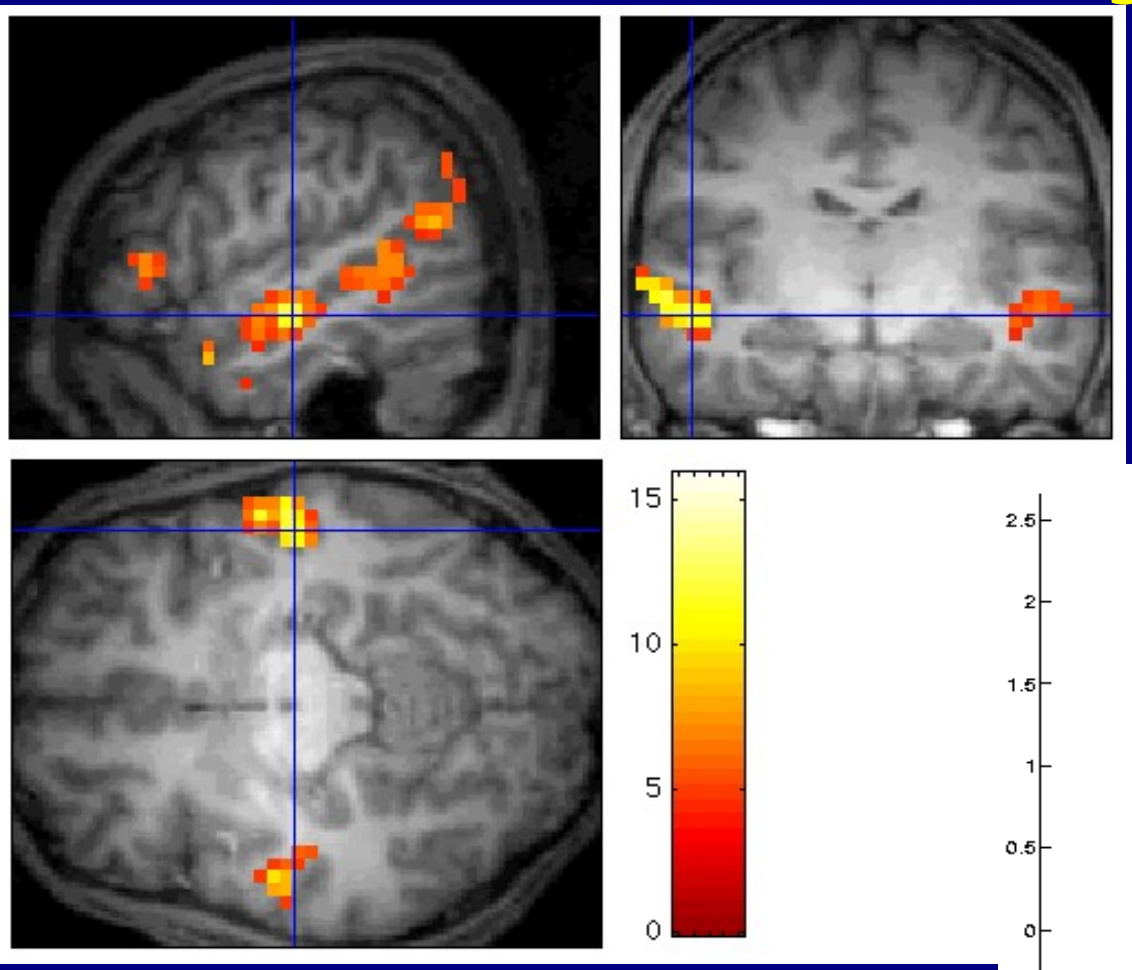
To induce subjects to pay close attention to the foreign sentences, they had perform a *probe detection task,* that is to decide whether a short speech fragment that followed the sentence came from it or not.

Results of probe detection

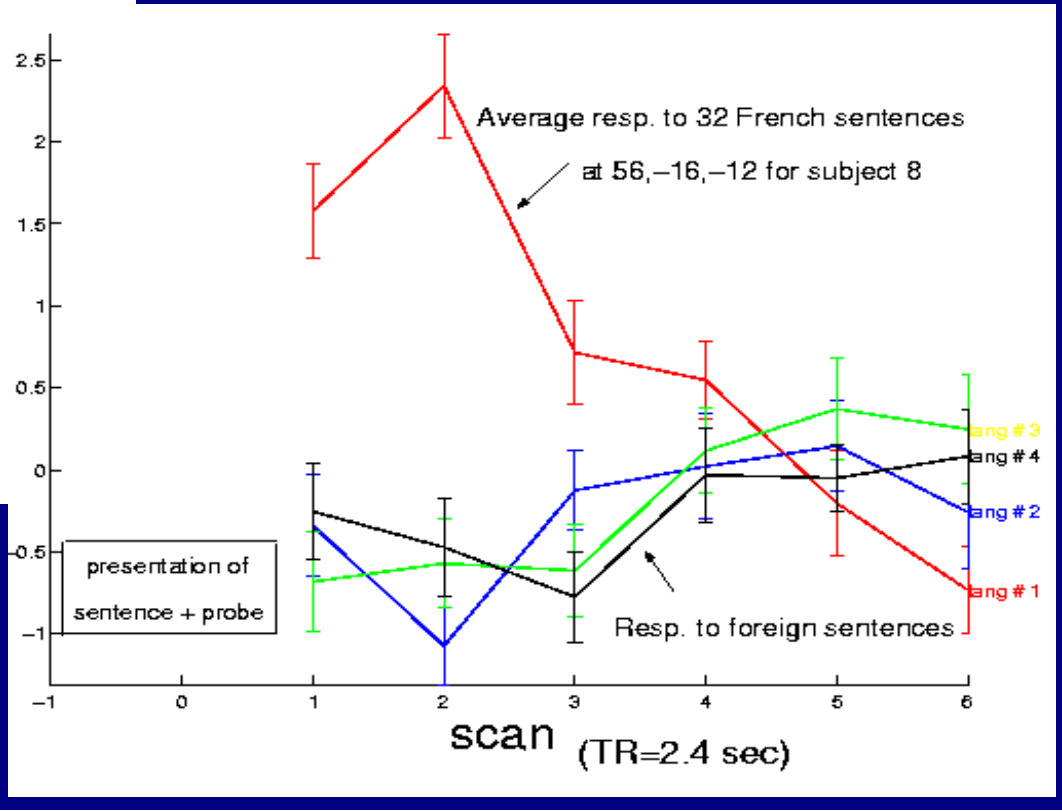


The performances of the adoptees and the native French do not differ.
Both groups performed better on the french stimuli.

Example of data in one French subject: areas showing more activation following French sentences than foreign sentences.



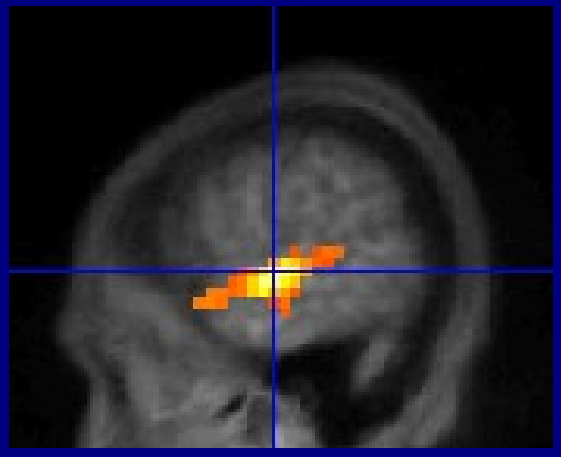
(threshold: p<0.05 FWE-corrected)



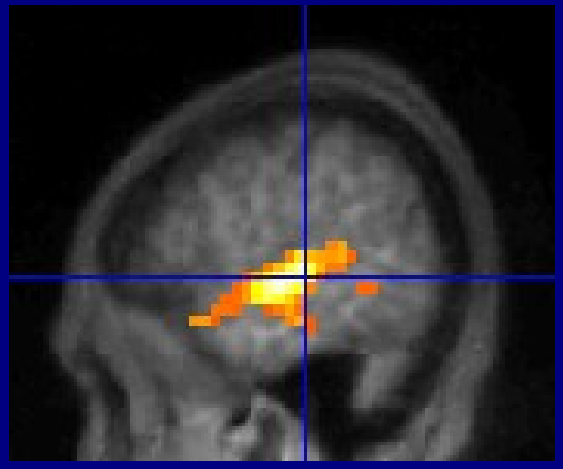
Activations elicited by Korean, Japanese and Polish stimuli.

- The sentences in the three foreign language elicited bilateral STG activations:

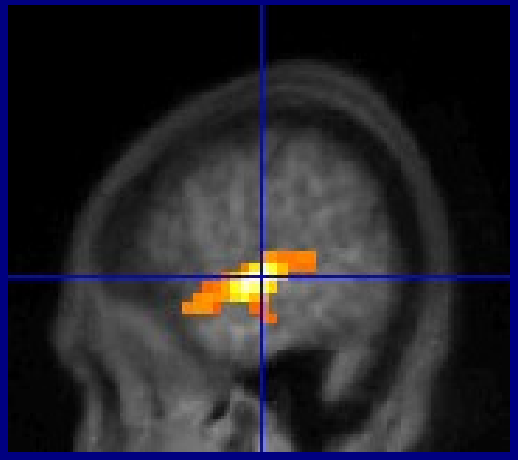
Korean



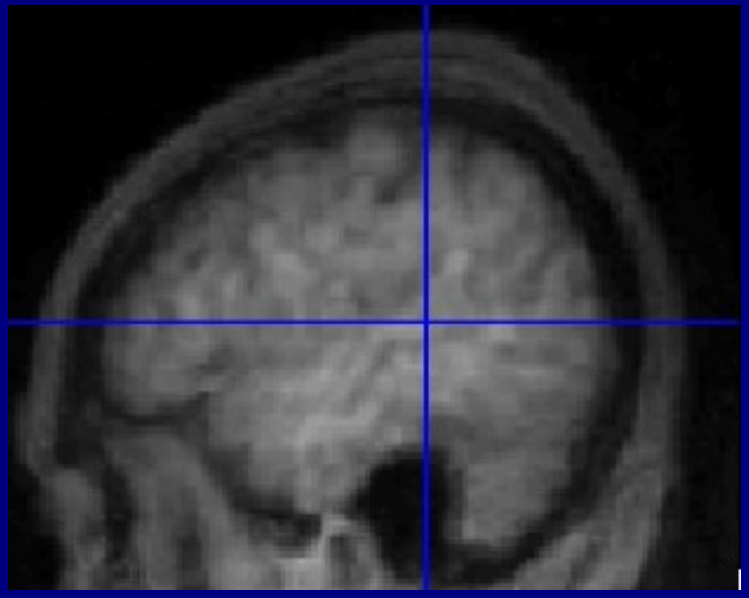
Japanese



Polish



Contrasting activations elicited by Korean, Japanese and Polish stimuli.



- The comparisons between the activations elicited by Korean, Japanese and Polish stimuli yielded no significant difference (nor in individual analyses, nor at the group level ($p<.01$ voxel-based).

Activations elicited by French stimuli

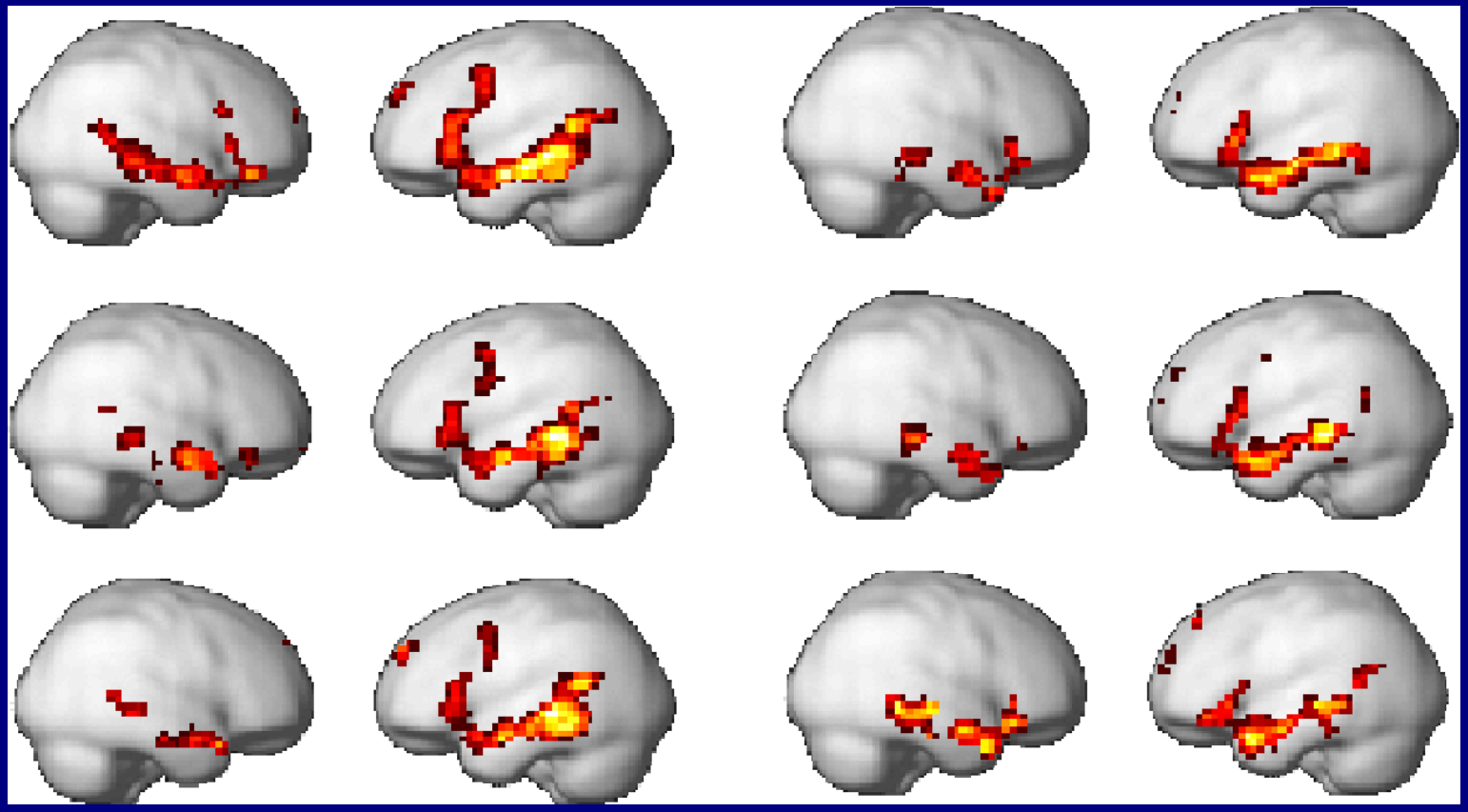
Native French subjects

Korean adopted subjects

Fr-Pol

Fr-Jap

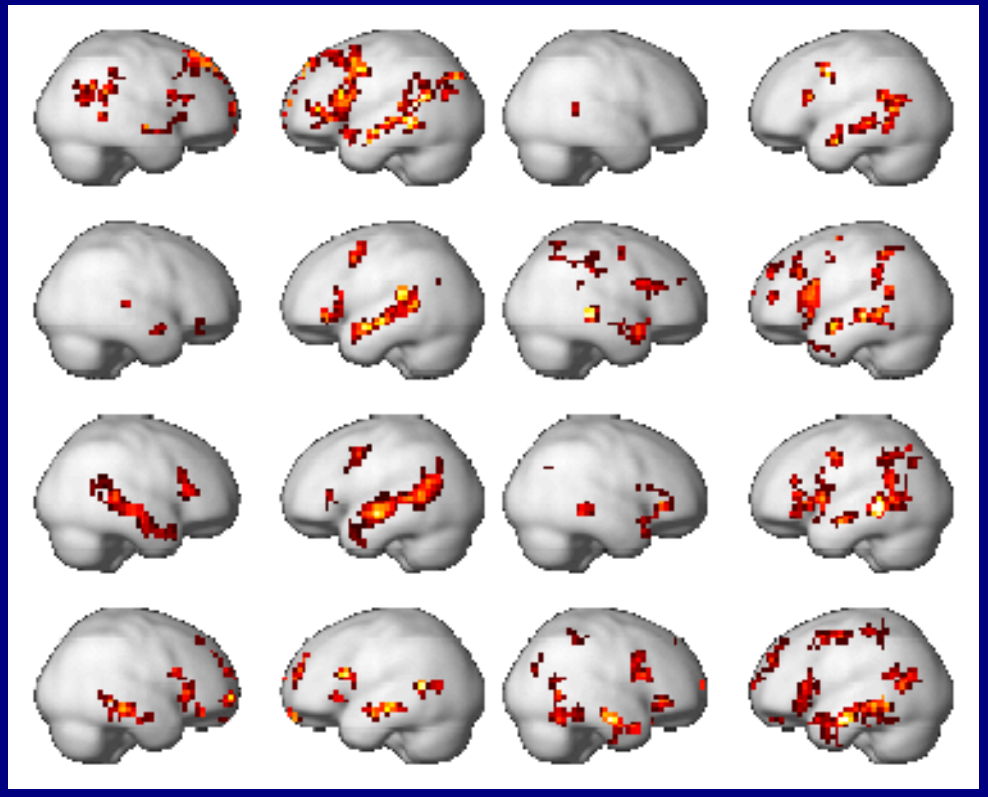
Fr-Kor



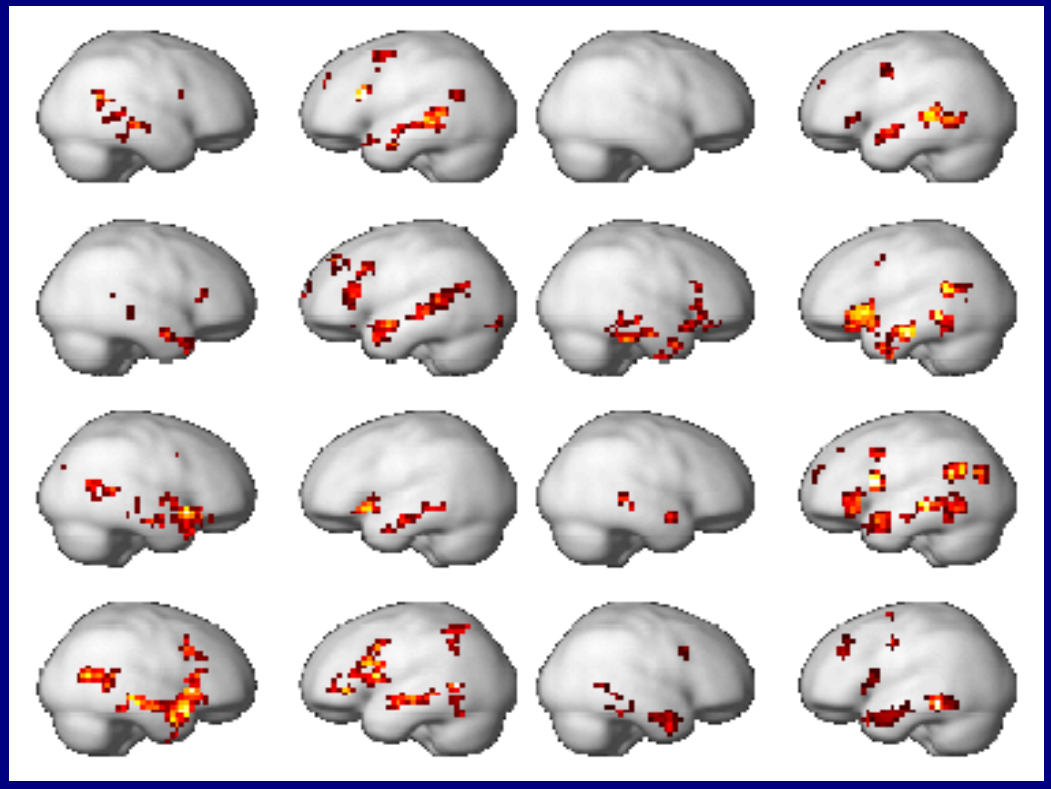
The patterns of activations were similar in both groups (with smaller extents for the Korean group)

Activations elicited by French sentences (French>Polish)

8 French Ss



8 Adoptees



The patterns of activation were similar in both groups, although the extents of activations were larger for the French Ss.

Confirm that L2 ~= L1 in highly proficient bilinguals.

Summary

- Listening to Korean sentences does not yield any specific activation in the adoptees.
- The patterns of activation were similar in the Korean adoptees and in the French native speakers.

There are two possibilities:

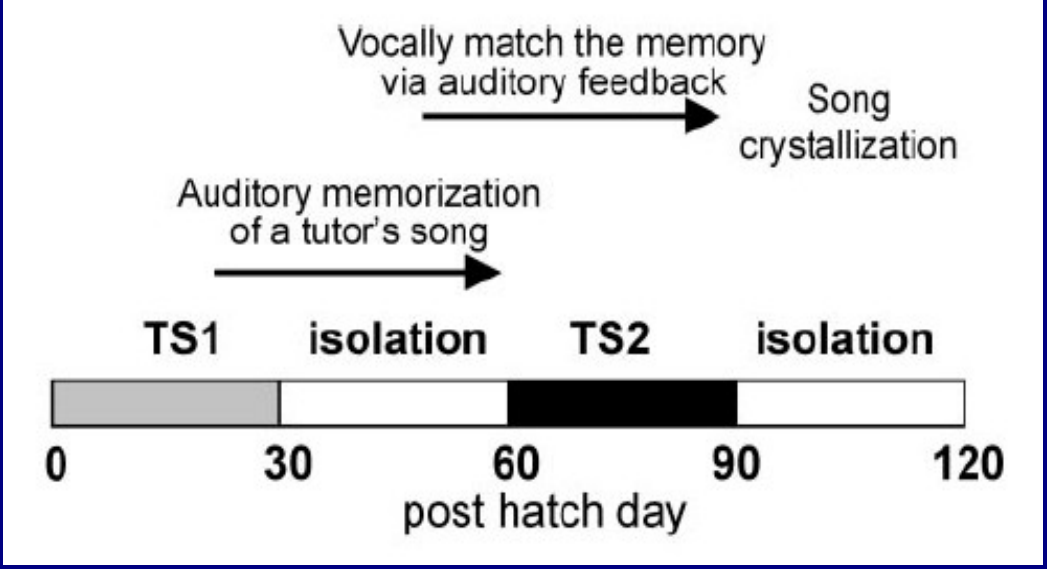
1. There are really not any traces of early exposure to Korean (contradicting the hypothesis that the circuits had started to crystallize)

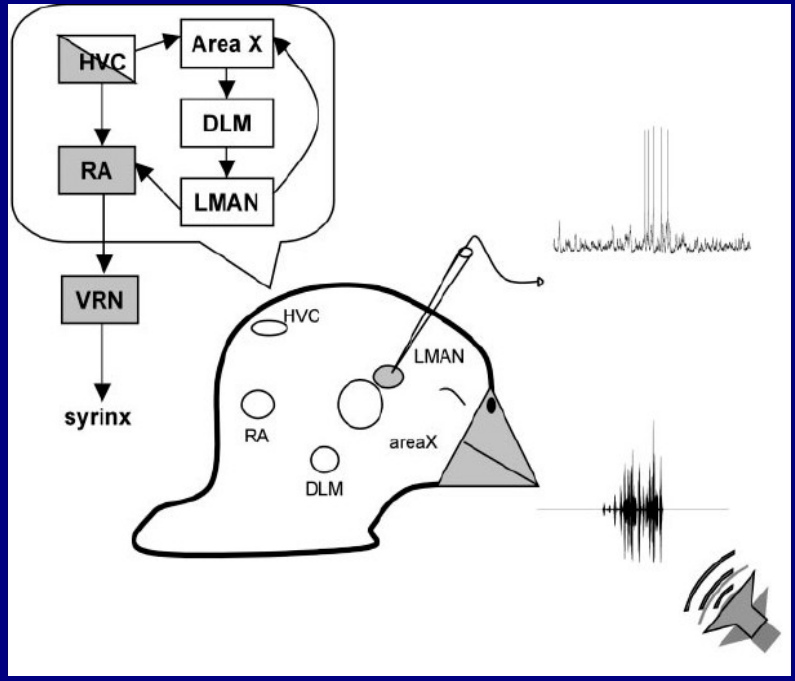
2. The methods we have used may have lacked sensitivity.

Retuning of auditory neurons in birds

(Yazaki-Sugiyama & Mooney (2004) Sequential learning from multiple tutors. *J. Neurophysiol.)*

22 zebra finch birds





"In adult birds, LMAN neurons respond to playback of the most recent tutor song but not to earlier tutor songs (or bird's own songs).
LMAN does not store information about transiently learned songs."

Follow-up experiments

(Thesis of Valerie Ventureyra, available at www.unicog.org)

Larger group of adoptees (20), including some who had been reexposed to Korean (touristic visits to Korea, from 10 days to 6 months) or had tried to relearn it.

Experiments:

- recognition of Korean words
- recognition of number series
- perception of Korean phonemic contrats
- sensitivity to phonotactics
- retraining the perception of phonetic contrasts
- recognition of Korean characters
- perception of European vs. Asian faces
- processing of French grammatical gender

Korean word recognition

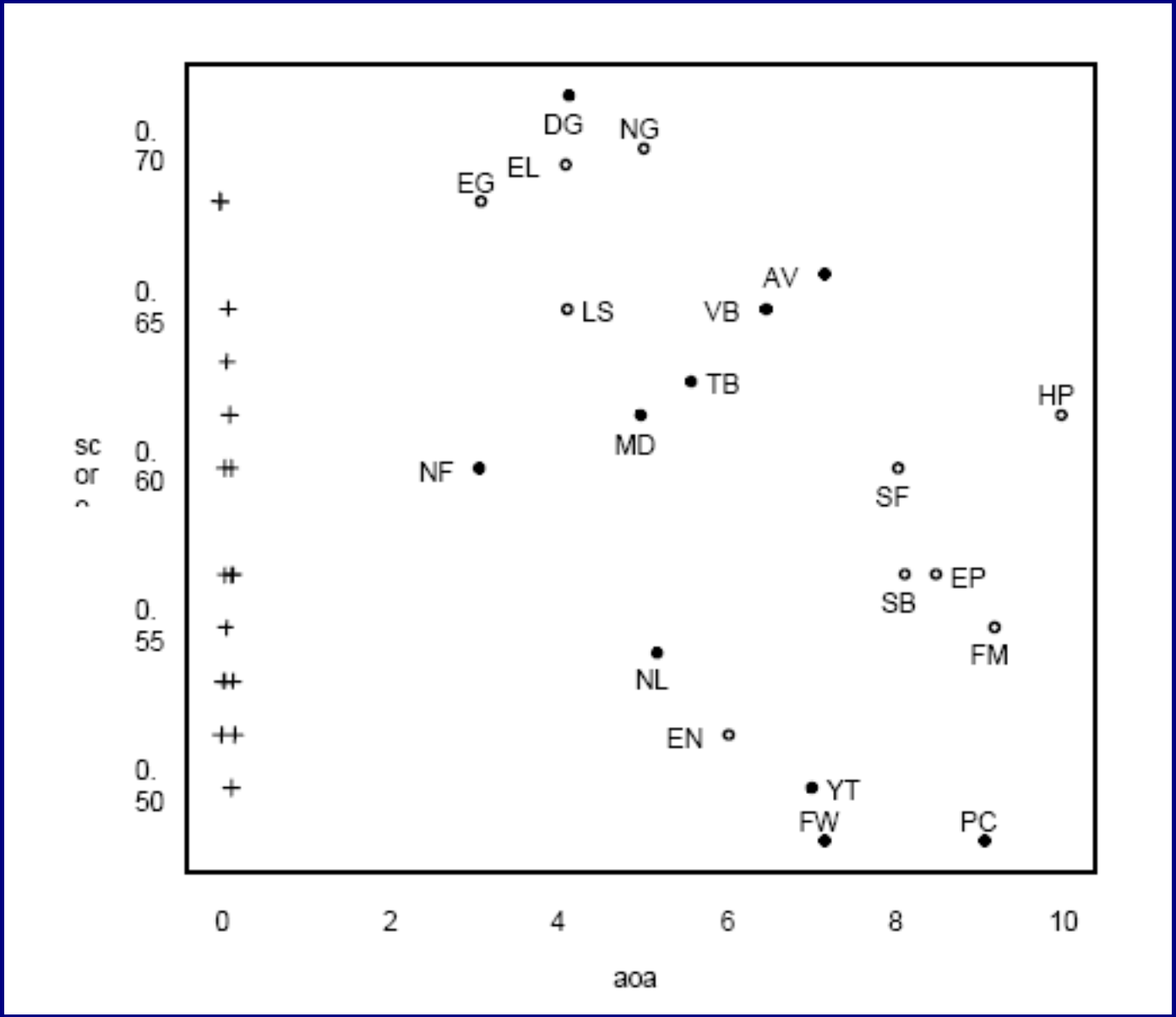
60 Korean words (many of them attested in a corpus of Korean 2 year-old children productions).

Task: Forced choice between 2 French words (selection of the translation).

Results:
'+': French Ss

Empty circles: adoptees (not reexposed to Korean)

Full circles: adoptees reexposed to Korean



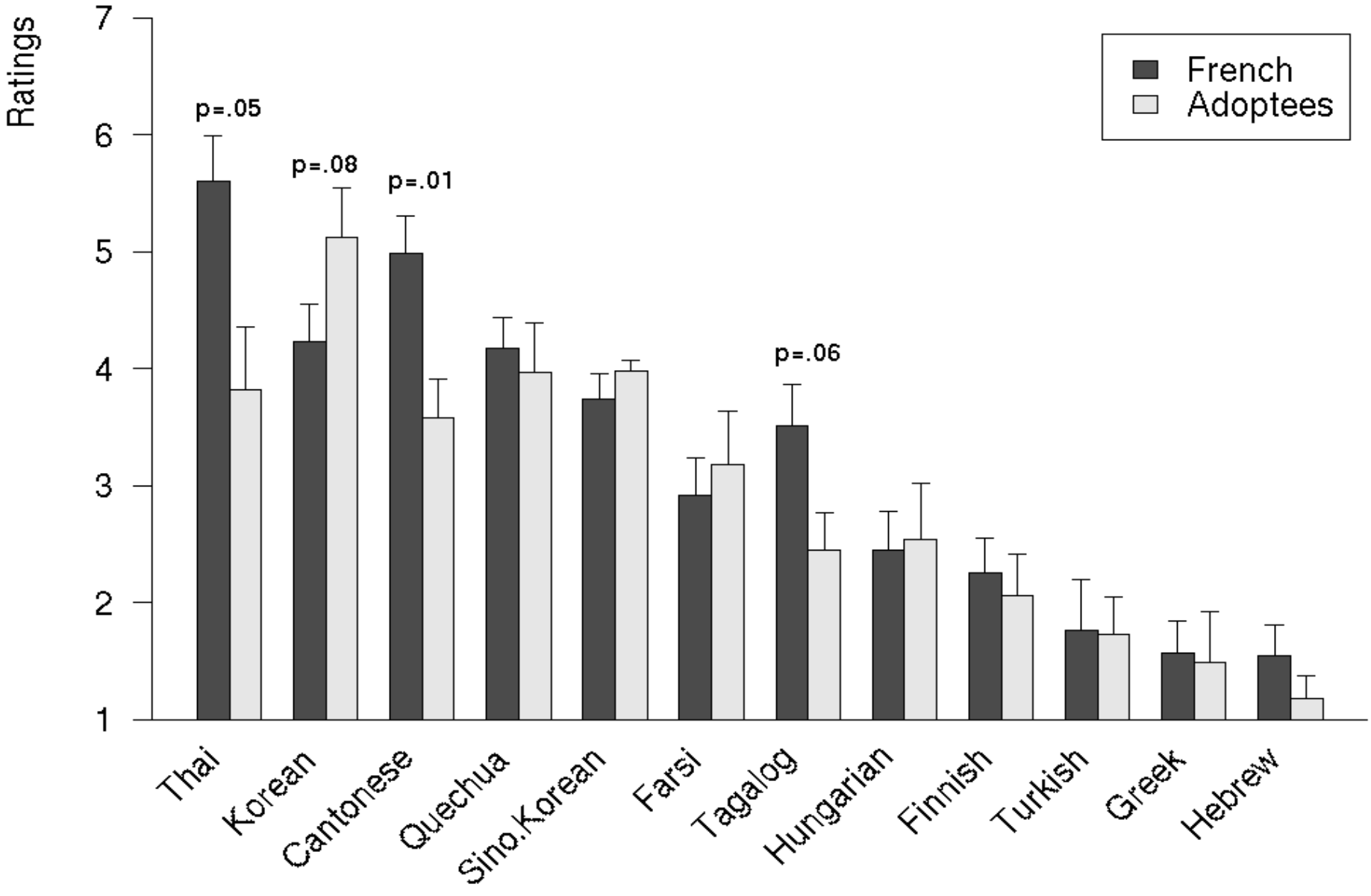
Recognition of number series

The participants listened to recordings of people counting (from 1 to 10) in 12 different languages

Task: rate on a scale from 1-7 the likelihood that it it Korean (7=sure it is Korean / 1=sure it is not Korean)

Remark: in Korean, there are two counting systems.

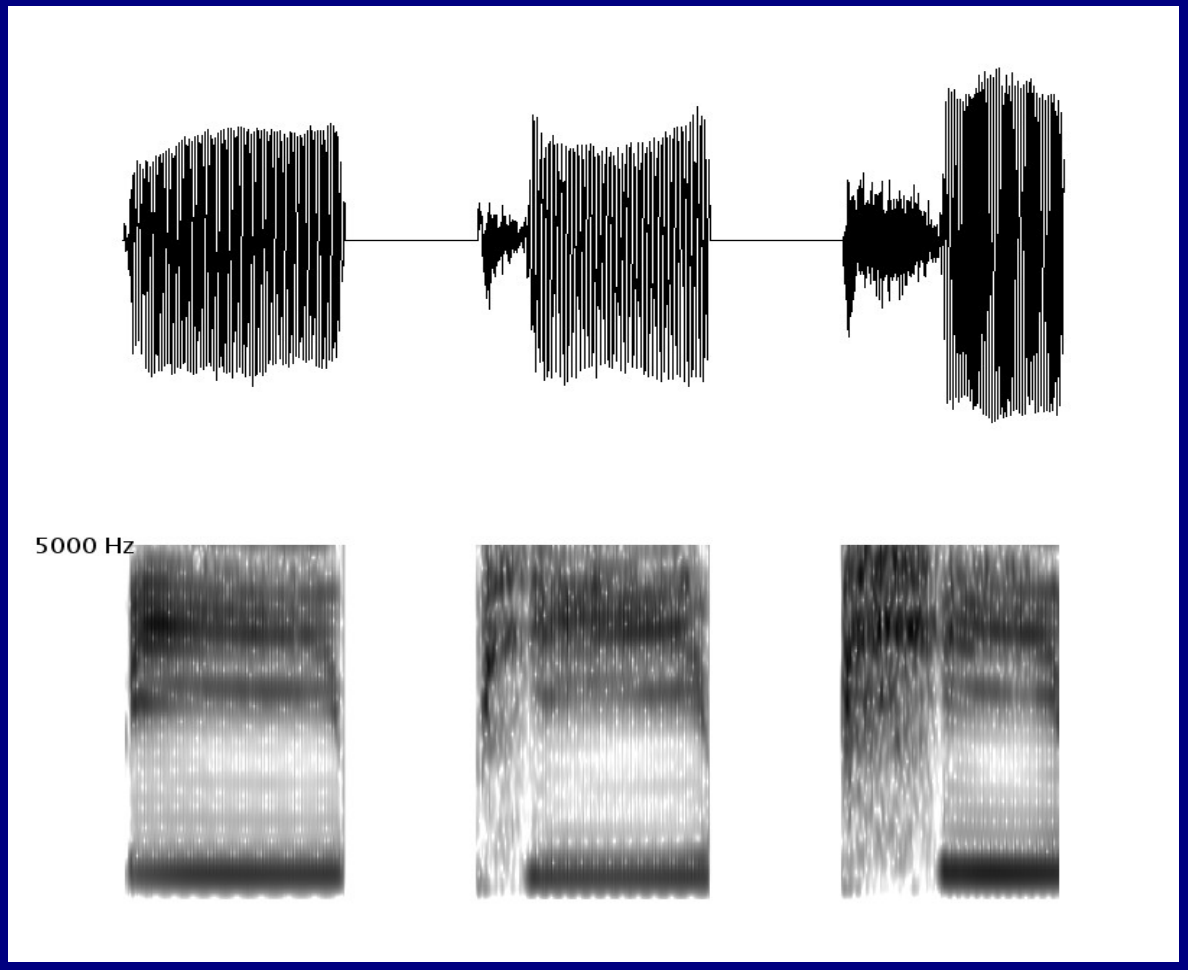
Recognition of number series



Korean phoneme discrimination

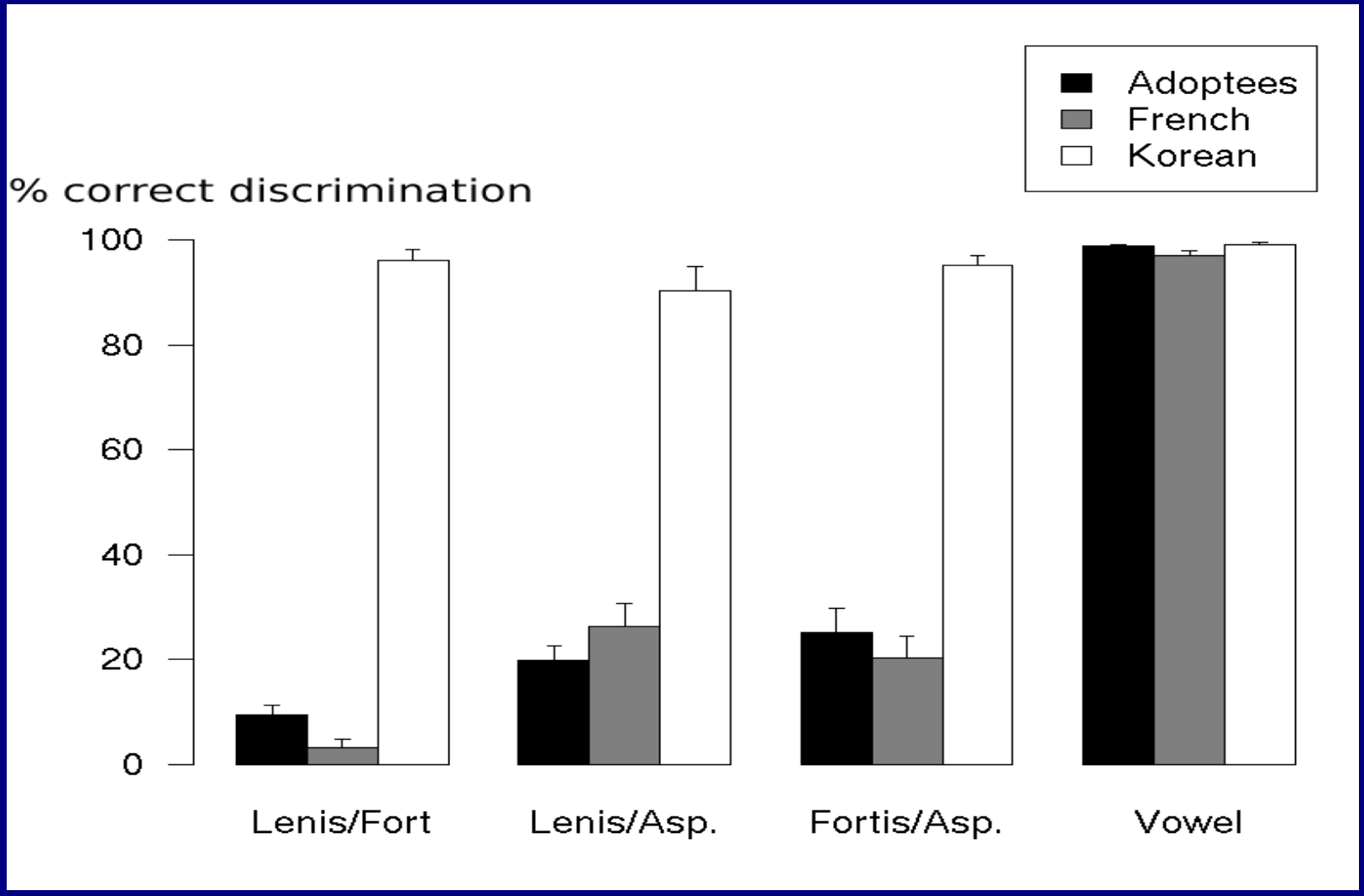
Korean voiceless stop consonants (p,t,k) have 3 variants: plain (lenis), tense (fortis), and aspirated.

These contrasts are difficult to perceive for French speakers.



Discrimination of Korean contrasts

AX comparison task with CVCV items that could differ in the first consonant or vowel.



(Ventureyra, Pallier & Yoo, *J. Neurolinguistics*, 2004)

Recognition of Korean alphabet (Hangul)

15 adoptees

17 French control Ss

Results

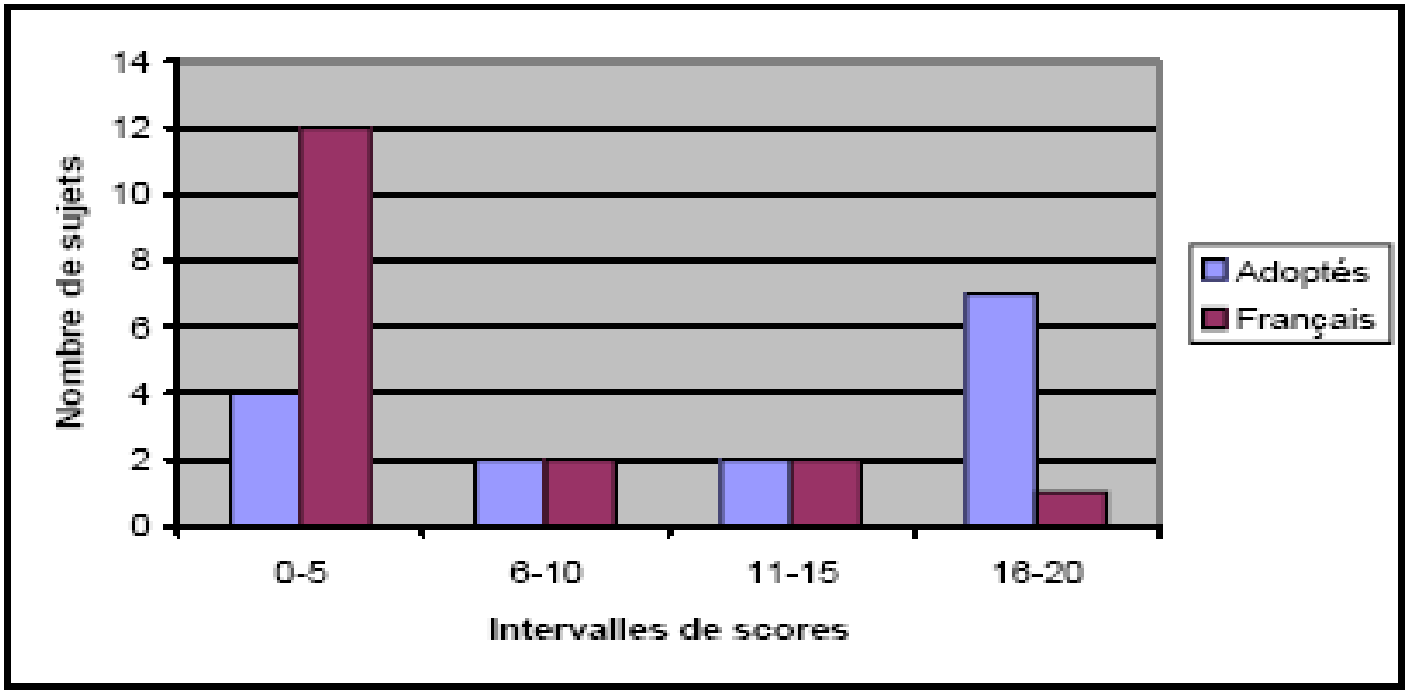


Figure 4.10. Graphique des intervalles de scores pour la reconnaissance des lettres coréennes par les adoptés et les sujets témoins francophones.

The Korean adoptees performed significantly better than French.

This is likely due to relearning/re-exposure

Summary

- Listening to Korean sentences does not yield any specific activation in the adoptees.
- The patterns of activation were similar in the Korean adoptees and in the French native speakers.

There are two possibilities:

1. There are really not any traces of early exposure to Korean (contradicting the hypothesis that the circuits had started to crystallize)

2. The methods we have used may have lacked sensitivity.

Re-learning of Korean phonemes

Would adoptees learn korean phonemes faster than native French ?

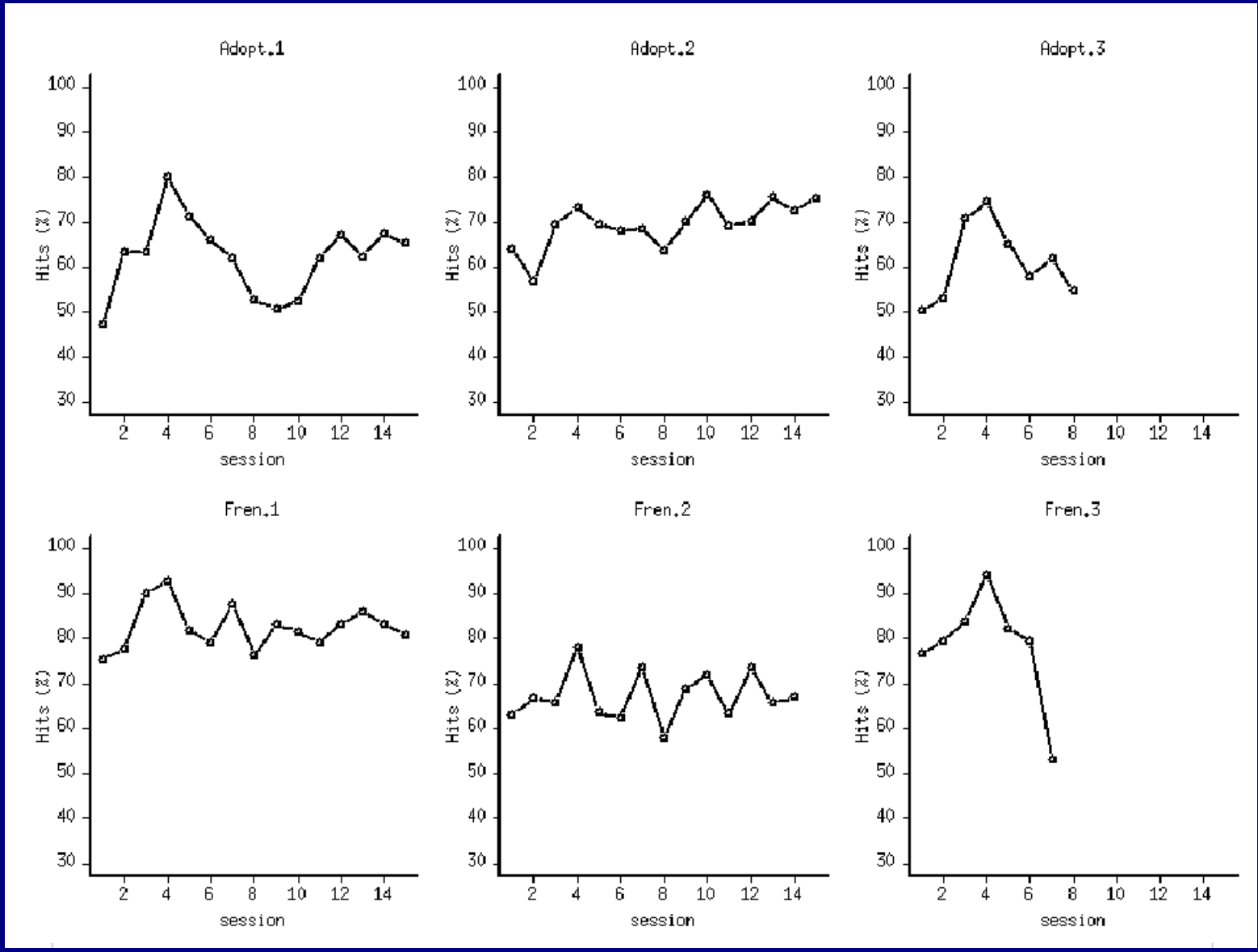
Design: The participants had to try and identify samples of lenis, fortis and aspirated [k] consonant.

The whole consisted in a series of 15 sessions of 30-minutes (6 speakers were used and the number of speakers in a session increased progressively).

Phonetic training: longitudinal evolution

3 adoptees :

3 french control subjects :



Conclusions of the training study

1. Not conclusive.

2. Quite hard to set up.

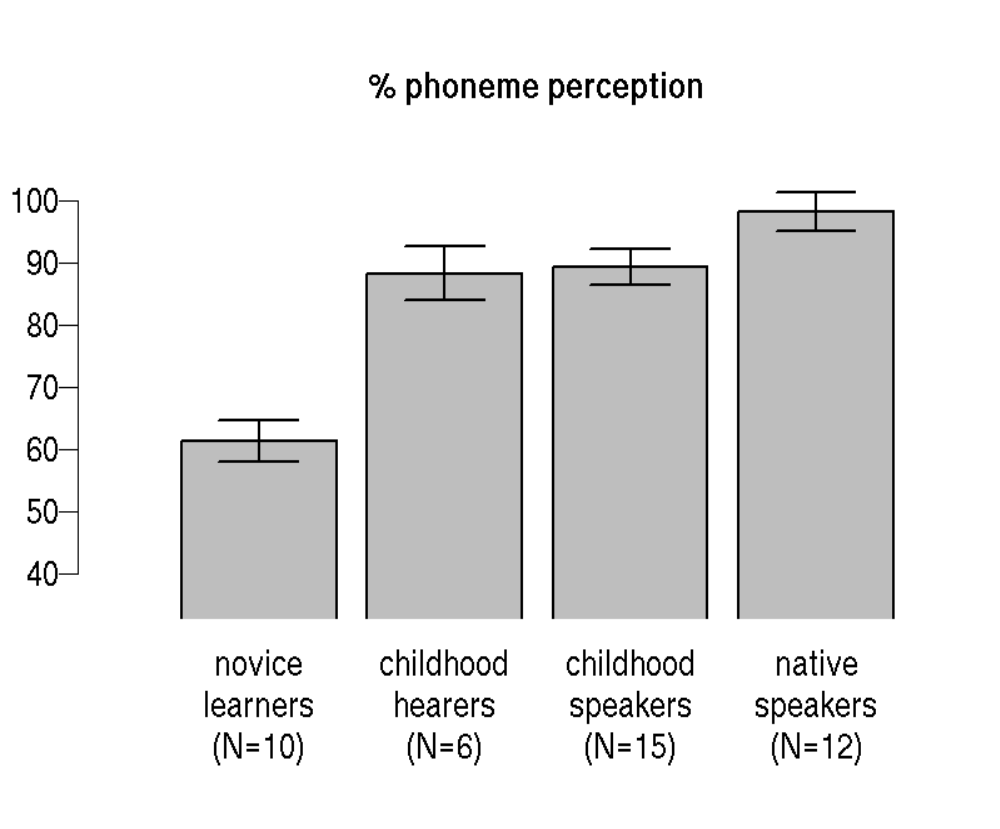
We should study subjects who are very motivated to learn Korean, and compare them to french subjects in the same situation (e.g. Students enrolled in Korean courses).

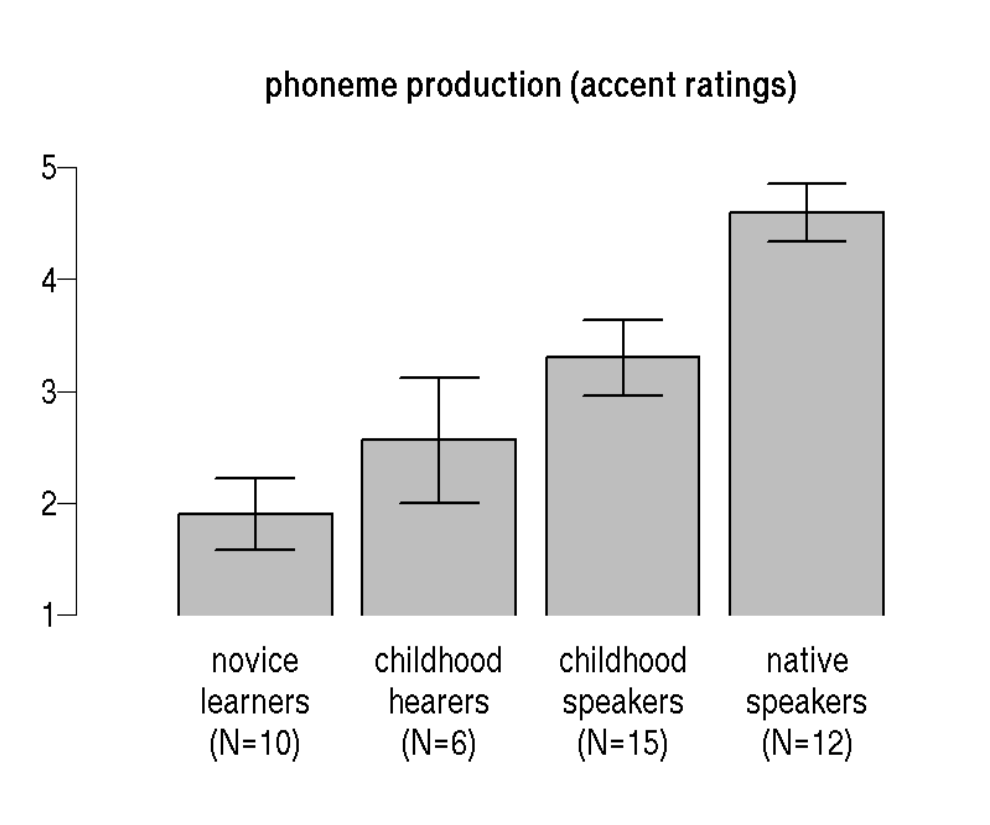
Evidence for lasting effects of early exposure

(Oh, Jun, Knightly, Au (2003). Holding on to Childhood language memory. *Cognition.)*

- Novice learners after 4months of Korean class
- Childhood hearers of Korean (~40h/week before age 5; 4.5h/week afterward)

  Childhood speakers of Korean (at least 3 years of use before age 7)





Differences between our study and the Oh et al. study

- Their Ss were tested 4 months after starting classes of Korean.
- Continuous exposure: Their subjects estimated that they heard about 4 hours/week of Korean.
- We cannot exclude the possible impact of emotional factors associated with adoption in adoptees.

Would adoptees relearn Korean faster or better than people who have not been exposed?

Preserved Implicit Knowledge of a Forgotten Childhood Language

(Bowers, Mattys & Gage, 2009, Psych. Sci)

Details of Early Language Experience for Participants With Zulu or Hindi Backgrounds

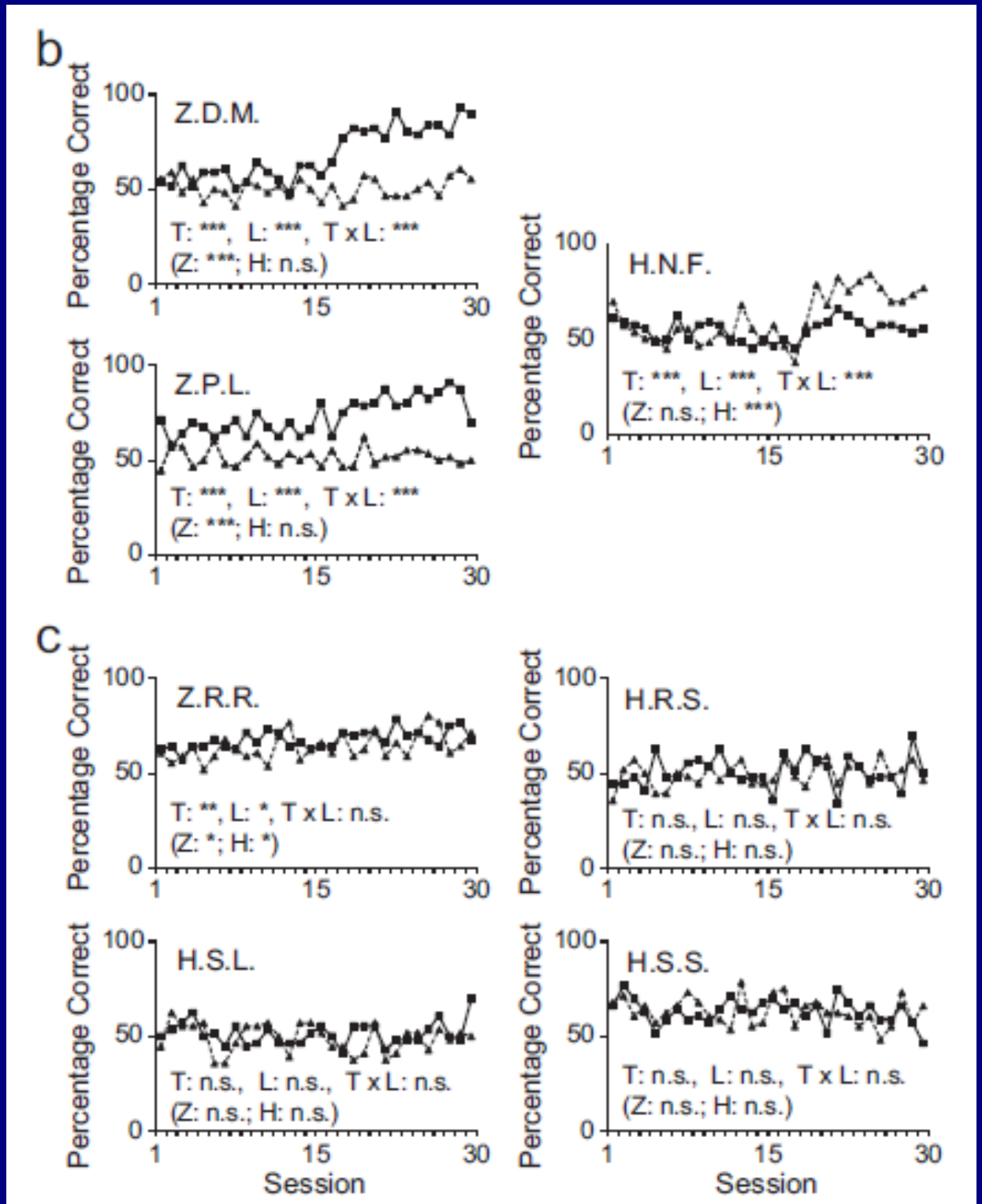
Participant	Gender	Age at exposure (years)	Years of exposure	Age at test (years)	Vocabulary score (out of 10)
	Zulu background				
Z.D.M.: was taught Zulu in primary school, but spoke predominantly English; "very poor" Zulu ability	Male	4	4	20	3
Z.P.L.: was cared for by Zulu nanny, who sang and talked to her in Zulu; heard some Zulu at home; spoke "very largely" English, with just "odd bits of Zulu"	Female	0	7	35	3
Z.R.R.: heard Zulu spoken by caretaker and family daily; was almost fluent in Zulu	Male	3	10	47	4
	Hindi background				
H.N.F.: heard Hindi spoken by family and nanny; achieved fluency of native 4-year-old Hindi	Male	0	4	34	5
H.R.S.: was fully fluent in Hindi	Male	0	7	50	4
H.S.L.: had Hindustani housekeepers and spoke to them solely in Hindi	Female	0	5	64	4
H.S.S.: brother of H.R.S.; was fully fluent in Hindi	Male	0	5	45	3

Stimuli: 1500 CVC syllables spoken by 12 different spearkers. First C:unvoiced dental-retroflex hindi contrast, and voiced dental-retroflex Zulu contrast.

Task: AX discrimination on first C.

Test: 30 sessions of 112 trials (~10 min/session). 1 session per day.

Results: see Figure:
L=language (Z or H)
T=time (first vs. second half of training)



Rapid reacquisition of native phoneme contrasts after disuse: you do not always lose what you do not use

Leher Singh,[1] Jacqueline Liederman,[2] Robyn Mierzejewski[3] and Jonathan Barnes[4]

Abstract
Infants attune to their birth language during the second half of infancy. However, internationally adopted children are often uniquely required to attune to their birth language, and then reattune to their adoptive language. Children who were adopted from India into America at ages 6–60 months (N = 8) and had minimal further exposure to their birth languages were compared to age-matched American non-adopted controls. Without training, neither group could discriminate a phonemic contrast that occurs in their birth language but not in English. However, after training on the contrast, the adopted group (N = 8) improved significantly and discriminated the contrast more accurately than their non-adopted peers. While English had explicitly replaced the birth language of the adopted sample, traces of early exposure conferred privileges on subsequent learning.These findings are consistent with behavioral and neurophysiological data from animals that have identified some of the mechanisms underlying such a ‘retention without further use’ phenomenon.

Recent Brain imaging evidence.

(Pierce et al. (2014) Mapping the unconscious maintenance of a lost first language, PNAS)

FMRI in 3 groups of children (9-17yrs):

- International adoptees L1=Chinese/L2=French without exposure to Chinese since adoption (before age 3; mean AOA=12months)
- French-Chinese bilinguals (L1=Chinese, then started learning Frenchbefore age 3),
- French monolinguals never exposed to Chinese

- Stimuli: short sentences of chinese pseudowords and hummed versions of these stimuli as control

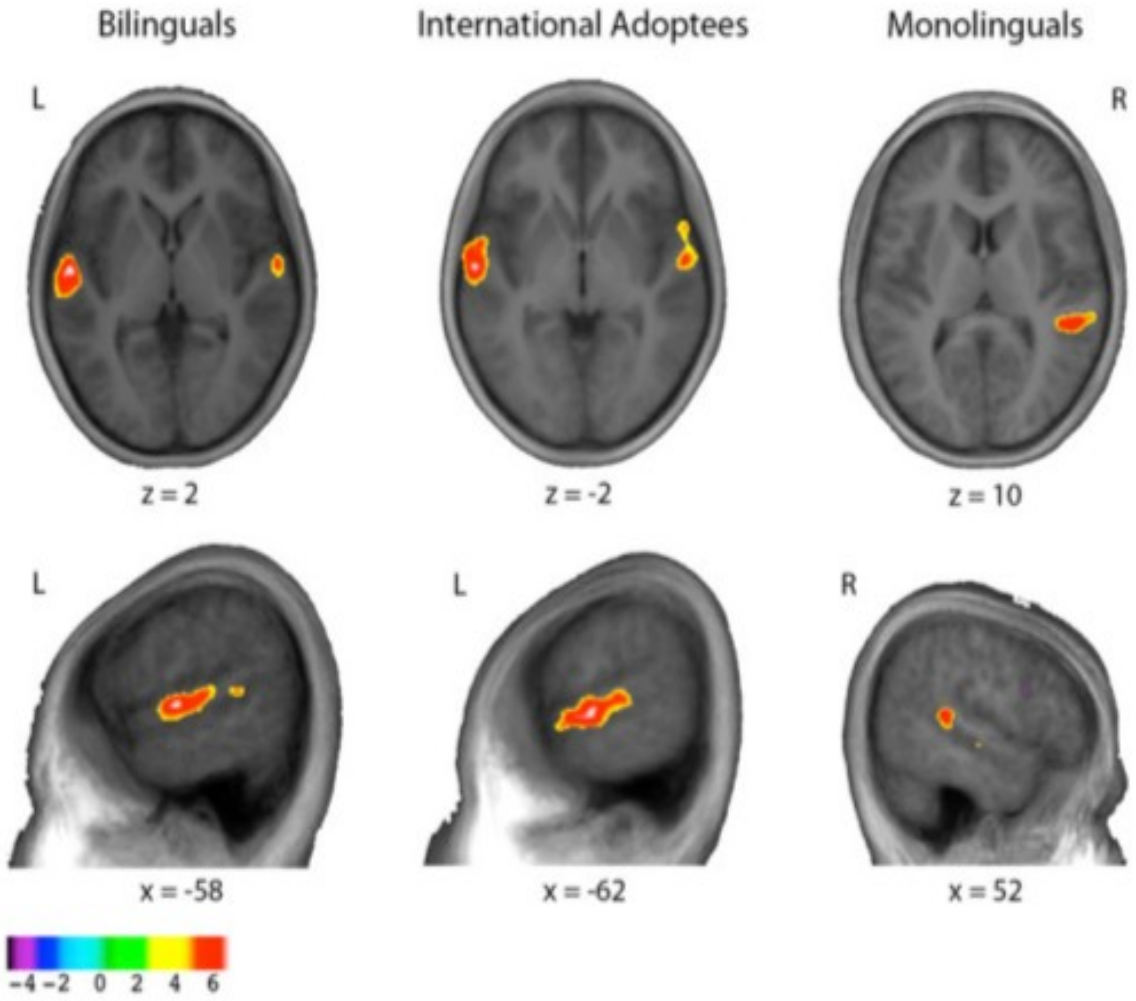


Fig. 1. *t* maps showing activation patterns for bilinguals ($n = 10$), IAs ($n = 10$), and monolinguals ($n = 10$) in a subtraction of the lexical tone minus hum conditions overlaid on the average anatomical t1 images of each group. Slices are shown in the axial (*Top*) and sagittal (*Bottom*) planes and are taken from the coordinate displaying the highest *t* value for each group in this subtraction. Note the strikingly similar patterns of activation for the IA and Chinese group and the contrasting pattern for the monolingual French group, supporting the notion of neural traces of a lost first language despite discontinued use.

Note: the direct statistical comparisons between the groups are not presented in the paper (?!)

L2 acquisition in international adoptees

Most IA children catch up quickly and perform within native-speakers norms on standardized language measures.

Quick lexical acquisition: After 3 months of exposure to English, adoptees (between 3 and 6 years) have a vocabulary size comparable to two-year-olds

(see also the single-case studies of Isurin (2000; 9yr russian girl adopted in the US) and Nicoladis & Grabois (2002; 17months old chinese girl adopted in the US).

Note that there is evidence of lags between IA and non-adopted children during the preschool and early school years (e.g. Cohen, Lojkasek, Zadeh, Pugliese & Kiefer, 2008 ; Delcenserie, Genesee & Gauthier, 2012 ; Gauthier & Genesee, 2011)

(quoted from Pierce et al. (2012). “Acquisition of English Grammatical Morphology by Internationally Adopted Children from China.”)

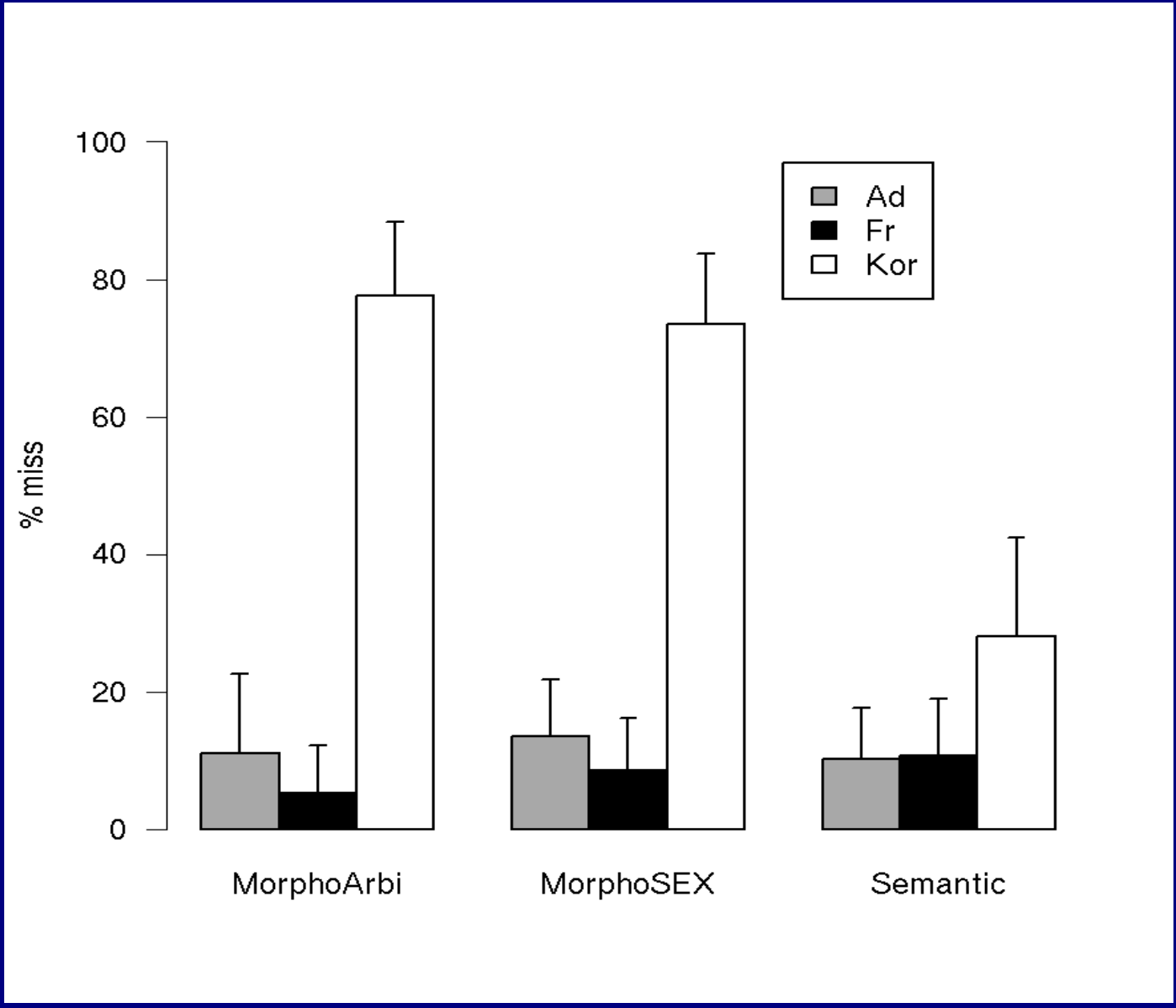
Assessment of proficiency in L2 (French): Detection of lexical gender errors

Koreans learning French have lots of difficulties with grammatical gender.

We had adoptees, native French and Koreans living in France for 2 to 7 years, listen to sentences which sometimes contained either gender agreement errors or semantic errors. For example:

```
(*sem)
  Il devait repeindre sa famille dans le sud avant la fin des vacances.
(*gender sex)
  Jacques lui offrit un magnifique chienne pour son anniversaire.
(*gender arbritrary)
  Il trouvait qu'il y avait un faible lumière sur cette photo.
```

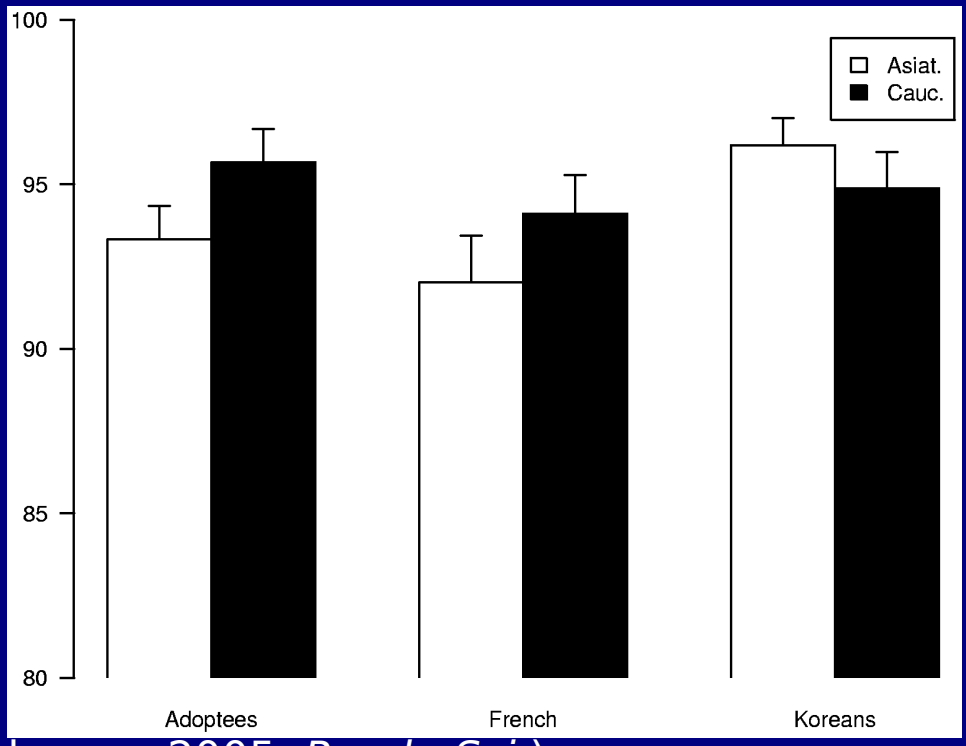
Detection of semantic and gender errors in French sentences



The “race” effect in face recognition

Adoptees, French and Korean subjects performed a face recognition task with Asiatic and Caucasian faces.

The Adoptees and the French performed better on the Caucasian faces than on the Asiatic faces. It was the reverse for Koreans.



(Sangrigoli, Pallier, Ventureyra, Argenti, De Schonen, 2005, *Psych. Sci.*)

Conclusion

- People who are adopted (until the age of 10) in a foreign country can apparently lose **most of** their first language (there are some remnants of phonetic kownledge) and seem to become native-like in L2 (more tests needed).

- The plasticity of language circuits is still very important at 10 years of age, provided normal exposure to a first language.

- Interestingly, studies of language attrition in adults show much less dramatic loss, maybe signaling end of CP between 10-20.

- We have not really tested the L1-L2 interference (we should compare adoptees to immigrants)

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