Perceiving non-native vowel contrasts: ERP evidence of the effect of experience

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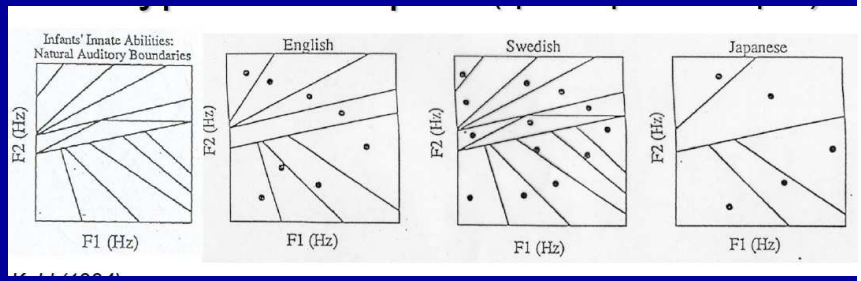
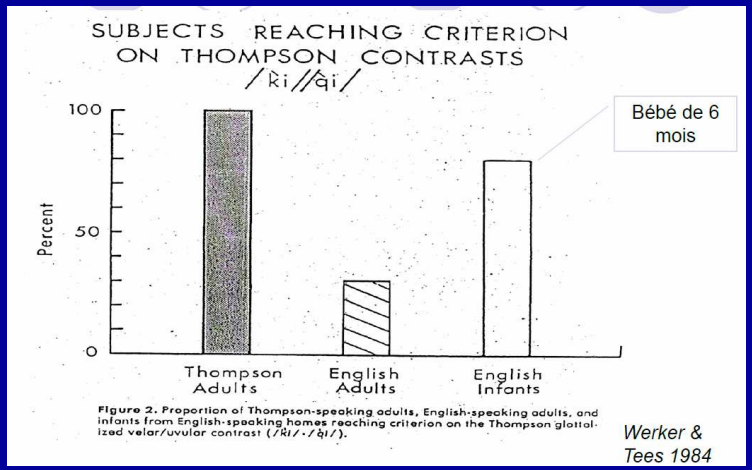
Language Attunement

- Well established that infants become « attuned » to the sound patterns of the language they are first exposed to (Kuhl, 1994; Iverson et al., 2003; Werker & Tees, 1984; Werker et al., 2008)
- Infants learn to attend to features that optimally distinguish contrastive sounds and to ‘‘weight’’ features according to their importance for the L1 phonetic system (Jusczyk, 1992, 1993).
- ‘Perceptual attunement’’ (Pisoni & Aslin, 1980)
- Question of interest:
  - How, and how well, can one learn non-native contrasts later in life?





Werker & Tees 1984

Even for simultaneous bilinguals, the nature of phonetic representation remains unclear

- Three competing hypotheses.
  - Bilinguals have a single phonetic representation that is the same for both languages and unlike that of a monolingual (Flege, 1987, 1995; Flege, Munro, and MacKay, 1995; Fowler et al. 2008).
    - Bilinguals, set category boundaries for consonants at locations that are somewhere in between native boundaries (Eng/Span; Fre/Eng).
  - Bilinguals have two separate independent phonetic systems, each like that of a monolingual (Grosjean, 1997).
    - If you control the « language mode », bilnguals will respond to perception and production tasks as a monolingual in both languages.
  - Bilinguals have a monolingual-like representation for one of their languages and a non-native representation for the other (Sebastián-Gallés et al., 2000; cf Cutler et al.,1989 in regards to word segmentation).
    - However: Burns, Werker & McVie (2003; 2007) have suggested hybrid results : some infants have 1 native system, some act like 2 monolinguals.

Models of L2 perception in « late » bilinguals

- Flege (1995,2003) Speech Learning (SLM)
  - « The capacities underlying successful speech acquisition remain intact across the lifespan »
    - Early experience shapes perceptual space (Kuhl)
    - L2 features absent in L1 will prove difficult (but not impossible) to aquire/perceive, and this will be reflected in production.
    - Early exposure (childhood) is better, however, doesn't guarantee success. Concomittant use of L1 plays a role.

- Best (1988, 1994, 2007) Perceptual Assimilation (PAM)

  Discrimination of non-native contrasts will vary as a function of how they map onto native categories
    - Single category (difficult)
    - Category goodness (fair – good)
    - Two categories (excellant)
    - Non assimilable (excellant)

Difficulties in perceiving non-native contrasts in late bilinguals: Behavioral evidence

- Extensive evidence that learning an L2 contrast is possible, however:
  - Early exposure to the L2 does not guarantee the formation of native-like phonetic categories, but is more likely if L1 use is infrequent. (Flege & McKay, 2004; Flege et al., 1999; Tsukada…Flege, 2003)
  - L2 contrasts that form a « single category » in L1 may not become « native-like » even for early learners (Højena & Flege, 2006).
  - Acquisition of L2 vowel contrasts is influenced by the phonological features present in L1 (McAllister, Flege & Piske, 2002)
  - Perception of L2 vowel contrasts is influenced by consonantal context (Levy & Strange, 2008)
  - Possible assymetries: « category goodness »
    - lexical representation > phonemic discrimination [æ] activates [E] + [æ] words, [E] activates [E] words only (Cutler et al., 2006; Weber & Cutler 2004; Escudero, Hayes-Harb & Mitterer, 2008)

Tentative conclusions from behavioral studies of both early and late learners

- Listeners initially weight the acoustic features of the input to optimally perceive their L1.

- When learning an L2, the speech signal will be « filtered » through these L1-tuned weights.
- As listeners receive more exposure to L2,
  - Initial weights will be realigned to classify new phonemic categories
  - the creation of new L2 categories is gradually established

- How well these categories are established depends on many factors:
  - The earlier in life exposure takes place the better, however even early experience is not a guarantee
  - Even in studies where very good performance is achieved, truly « native-like » performance is very rare.

- Flege « enough to suggest that there is plasticity »
- Sebastian-Galles « even simultaneous bilinguals have one dominant, « L1 system » which precludes formation of true L2 categories.

Evidence of L2 phonemic perception from electrophysiology (ERPs)

- Has been argued that behavioral studies do not provide evidence of « automatic » processing, but, rather « late, effortful and conscious » processes.
- Hence, overt metalinguistic knowledge may play a role (eg Weber & Cutler,2004; Cutler et al., 2006).
- Electrophysiology may provide a means to examine whether new categories are fully-formed, automatically activated.
  - MMN (widely used) : provides information about pre-attentive, automatic phoneme detection
  - N2-P3 (more rarely): shown to be sensitive to phonemic category boundaries (Maiste et al., 1995; Frenck-Mestre et al., 2005)

Electrophysiological evidence of phonemic processing : Mismatch Negativity (MMN), N100,N200, P300

- Basic oddball paradigm

  Present a majority of « standard » stimuli (ta ta ta …) 98%

  Interspersed with one (or more) « rare » (ta ta ta ta ta ta DA) 2%

  The « rare » stimulus provokes an auditory ERP response, which can be due to either acoustic or phonemic processing

<u>« Automatic » Pre-attentive</u>

- **Auditoy N100** : Early 'acoustic' response (also sensitive to stim frequency)
- **MMN** : pre-attentive response

  -based on memory trace of sensory input, sensitive to physical differences

  -has a phonemic component: native contrasts produce larger response

<u>Task dependent, conscious perception</u>:

- **N200** : Attentional response linked to task demands, reward
- **P300** : (P3b) Attentional response associated with conscious categorisation; « updating » of the sensory trace,

  -highly sensitive to frequency of task-relevant stimulus

  -amplitude increases as frequency decreases

  -latency can reflect difficulty of stimulus categorisation

Electrophysiological evidence (MMN) of L2 acquistion of non-native contrasts

- Winkler et al. (1999)
  - Evidence of native-like response to new phonemic categories in adults, following several years of L2 immersion
- Peltola et al. (2003)
  - Did not replicate finding, with advanced L2 learners (12 years of study) **not immersed**. smaller MMN than for natives
  - « New native-like long-term memory traces for foreign vowels are not formed despite extensive training »
  - Found reduced response even for native categories in L2 learners : suggest stage of transition.
- Peltola et al. (2005)
  - Found evidence of L2 categories **in children** immersed for 3 years

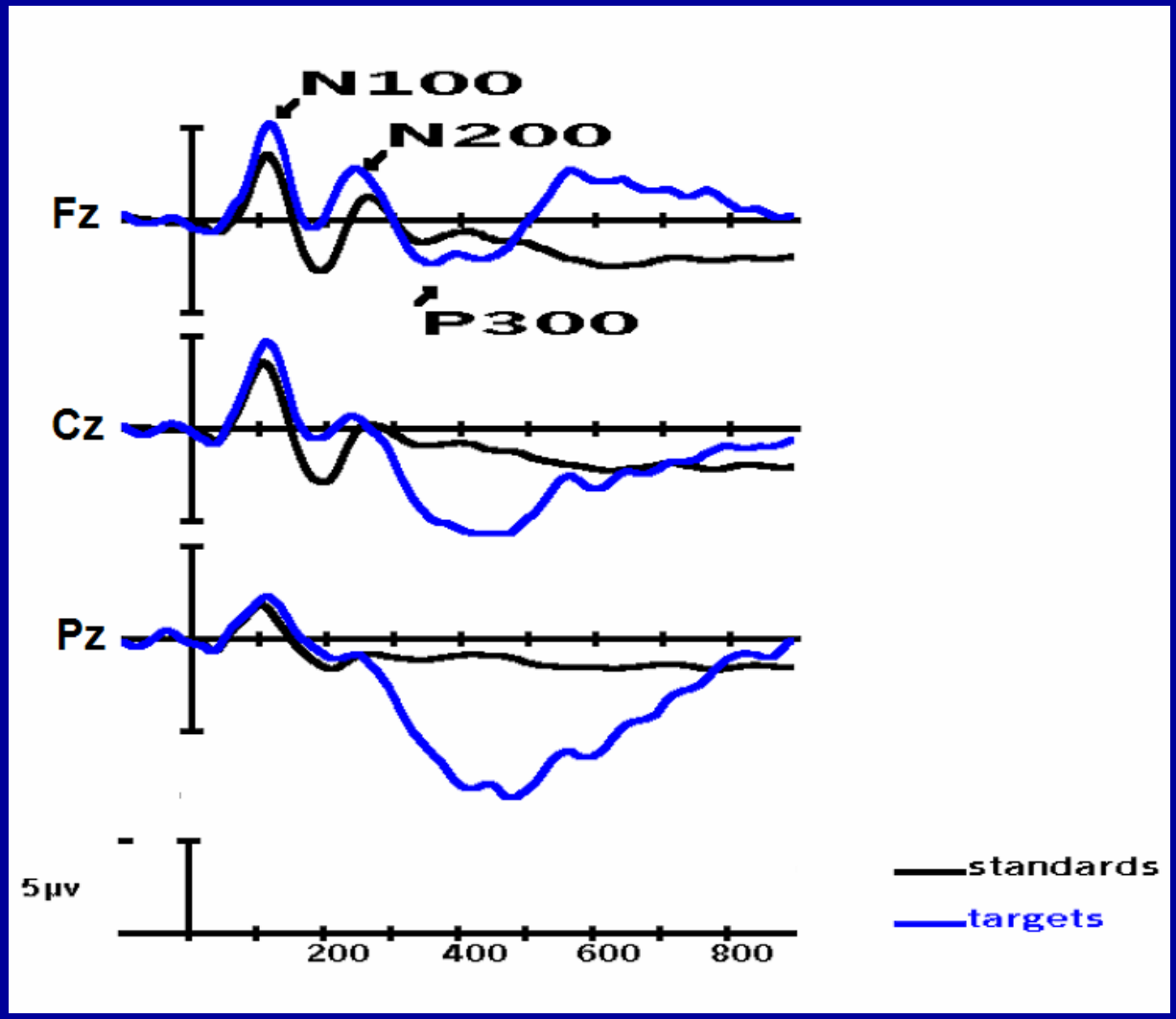
Detection of acoustic differences (N100) vs Conscious categorization (N2-P3) of L2 contrasts

- The MMN has been successfully used in numerous experiments to show
  - effects of L1 attunement
  - necessary conditions to develop sensitivity to L2 contrasts
- However, the MMN is indicative of automatic, pre-attentive phoneme perception.
- What happens downstream? Is there sufficient conscious categorization of L2 contrasts to result in a subsequent P300?
- Evidence that boundaries of native contrasts can be seen in differences in N2-P3 complex (Frenck-Mestre et al., 2005; Maiste et al., 1995).
- Can we observe « automatic » categorization of unattended vowels in the P3 response?

ERP signatures of interest for the present study

- N100 : early acoustic processing (Näätänen & Picton, 1987; Näätänen, 1987; Picton et al., 2000; Winkler et al., 1999)
  - Should vary as a function of the vowel, due to differences in vowel quality (formant values) and perhaps acoustic distance (ae>I>E)
- N2b : overlaps the MMN, but linked to active processing; indicative of a more phonemic level (Maiste et al., 1995; Winkler,Kujala, et al., 1999).
  - Should vary as a function of the role of the vowel
- P3b : categorisation of the stimulus; conscious « updating », closure (Freidman, et al. 2001; Spencer, Dien, & Donchin, 2001, for recent reviews)
  - Should vary as a function of the Role/Frequency of the vowel
  - Should vary as a function of whether vowels are categorized as different from standard stimulus vowel.
  - Of interest is response to oddball (not target)

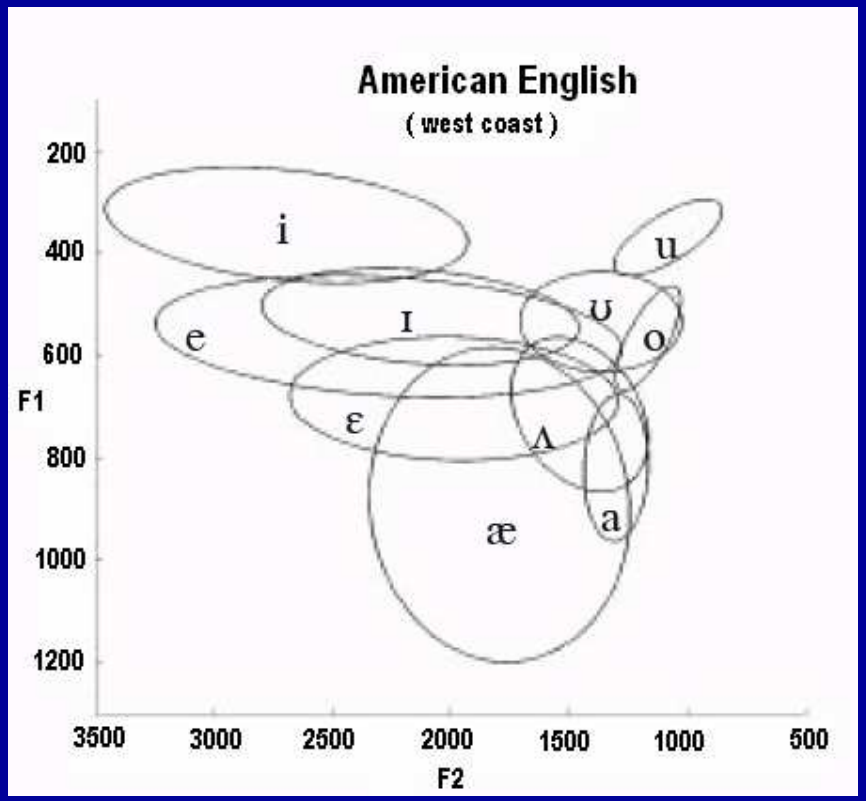
Present study: detection vs. categorisation acoustic : N100 vs. phonemic Attentional (N2-P3)

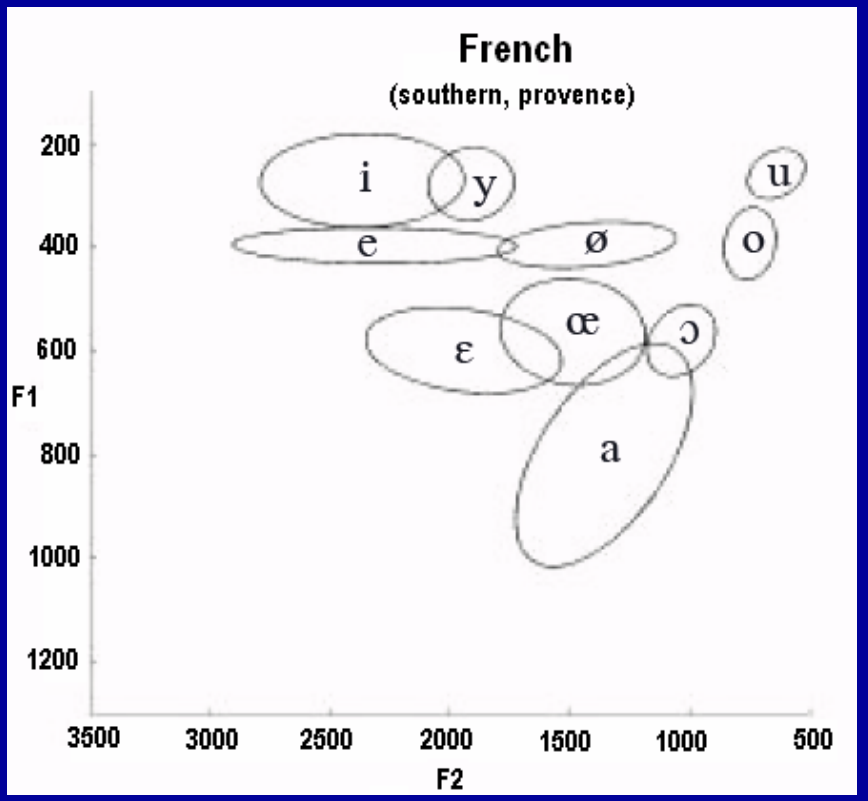


Present Study: Behavioral and ERP evidence of vowel perception and conscious categorisation in L1 and L2

- First behavioral study: used to determine vowel space
  - Examined the vowel space of L1 French and English in production (Meunier, Frenck-Mestre et al., 2003).
  - Established patterns of assimilation of vowels across languages : of interest – English vowel assimilation into French native categories (Meunier, Frenck-Mestre et al., 2004).
- First ERP study
  - Examine categorization of English vowels by English and French « monolinguals » (Frenck-Mestre, Meunier et al., 2005)
  - N100
  - N2/P3
- Second behavioral study: determine vowel perception of L2 English vowels by advanced late learners, L1 French (Peri & Frenck-Mestre, 2007)
- Second ERP study (two experiments):
  - replicate results of first study for « monolinguals »
  - Examine performance of advanced late learners, L1 French
  - Examine the effect of task demands

Production of French and American English oral vowels by native speakers





4 native speakers (2 male, 2 female); 10 tokens of each vowel, in three contexts

Meunier, Frenck-Mestre et al., 2003

Vowel categorisation grid (10 vowels x 4 exemplars x 4 speakers (2 male, 2 female) x 3 languages) : 20+ participants per native group

1			X							
	sot	sort	sa	ceux	sœur	sous	fée	fait	cire	sur
2							X			
	sot	sort	sa	ceux	sœur	sous	fée	fait	cire	sur
3					X					
	sot	sort	sa	ceux	sœur	sous	fée	fait	cire	sur
4	X									
	sot	sort	sa	ceux	sœur	sous	fée	fait	cire	sur
5										X
	sot	sort	sa	ceux	sœur	sous	fée	fait	cire	sur
6				X						
	sot	sort	sa	ceux	sœur	sous	fée	fait	cire	sur

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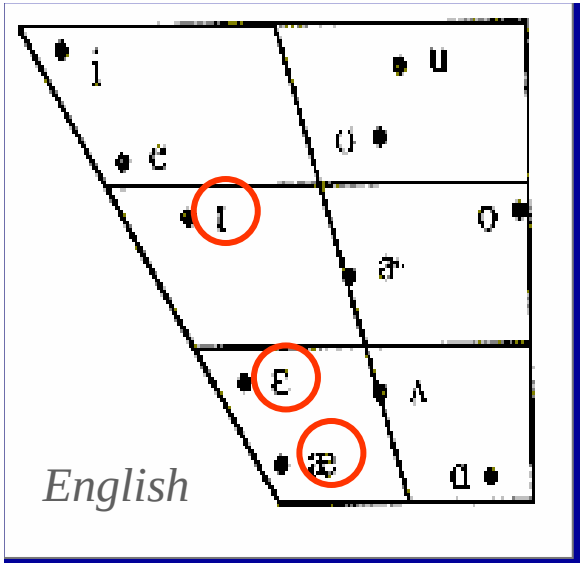
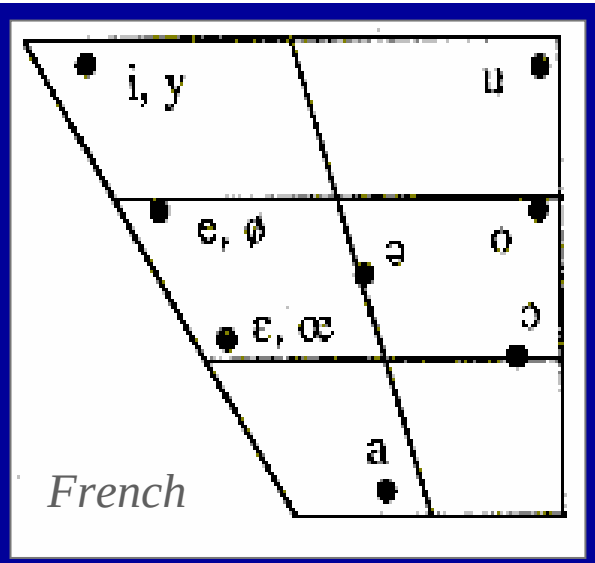
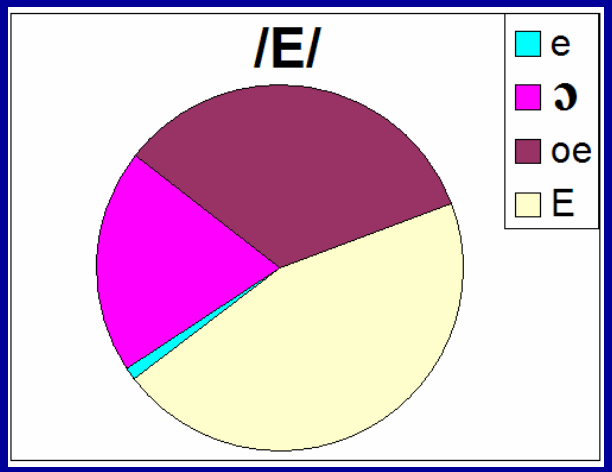
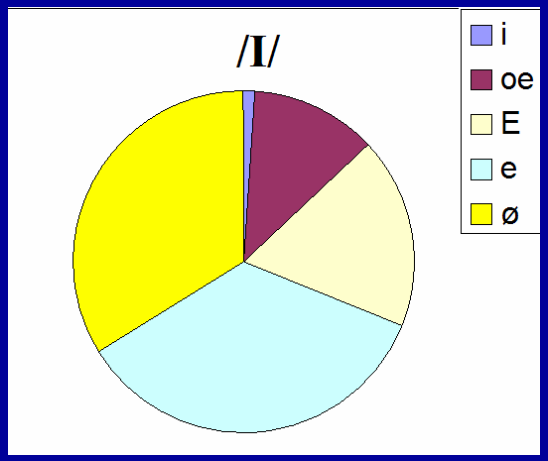
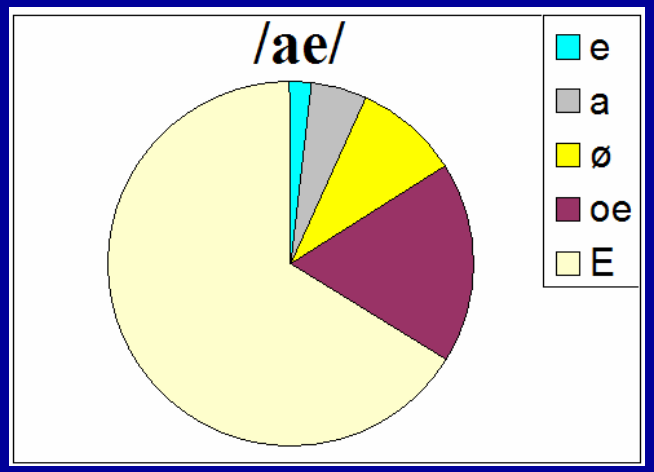




Behavioral classification of American-English Vowels by French « monolinguals »







Meunier, Frenck-Mestre et al., 2004

ERP study of native AE contrast /**I**/ - /E/

for native L1 English vs. native L1 French

- Participants:
  - Native American-English (N=15, mean age 22 yr)
  - Native French, with only secondary school English (N=15, mean age 22 yr)

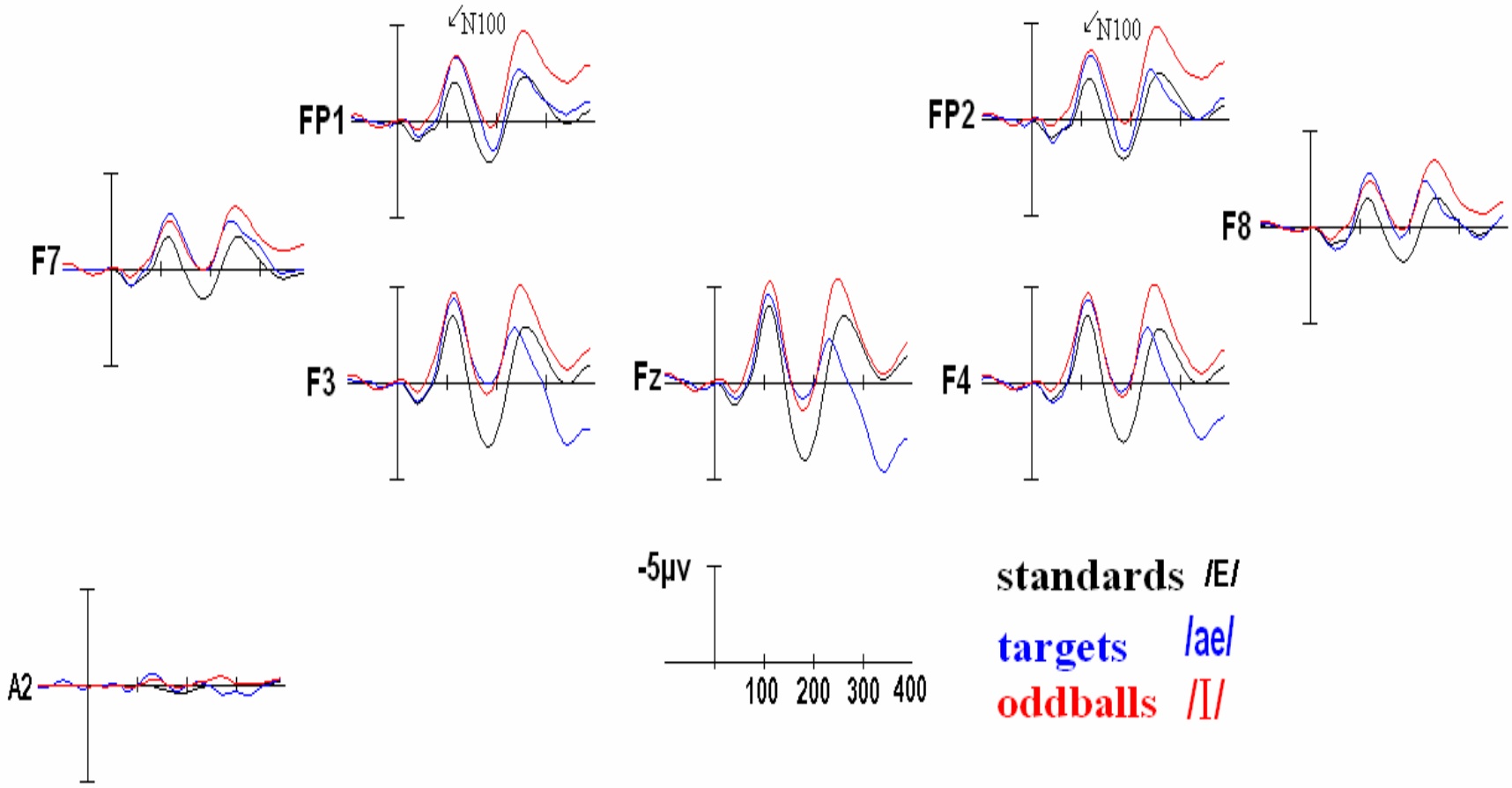
- Methode : ERP recording (32 channels)
  - 3 stimulus oddball task
- Stimuli : 3 English vowel categories (7 exemplars of each, extracted from /h_d/ context; 140ms duration; 1 sec ISI)
  - Standard /E/ 82%
  - Target /ae/ 3%
  - Deviant /**I**/ 15%

- Task : mentally count target /ae/ (give count at ¼, ½, ¾, end)
  - not informed about inclusion of deviant /**I**/

- ERP signatures of interest:
  - N100 (acoustic discrimination)
  - N2-P3 : conscious categorisation

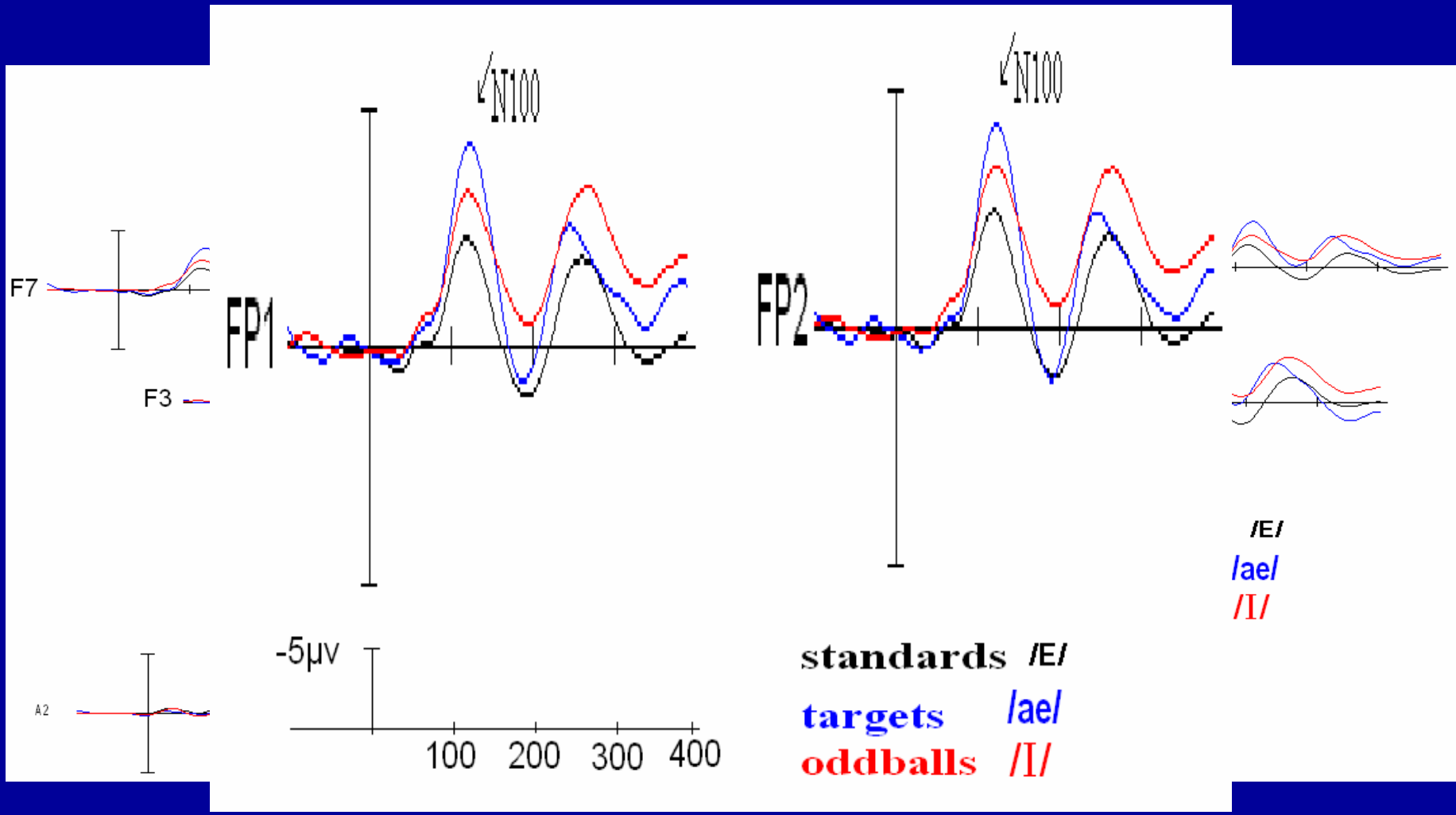
Frenck-Mestre, Meunier et al., 2005

L1 English speakers N100 response to three native vowel categories



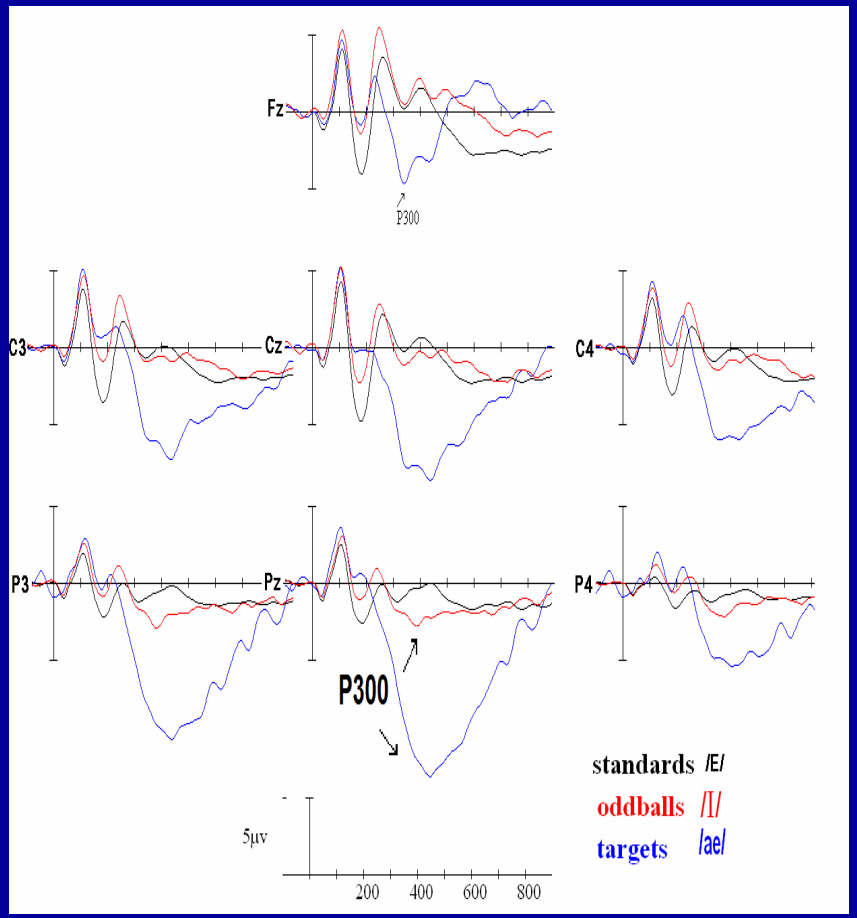
Frenck-Mestre, Meunier et al., 2005

L1 French (not fluent in English) N100 response to American English vowels

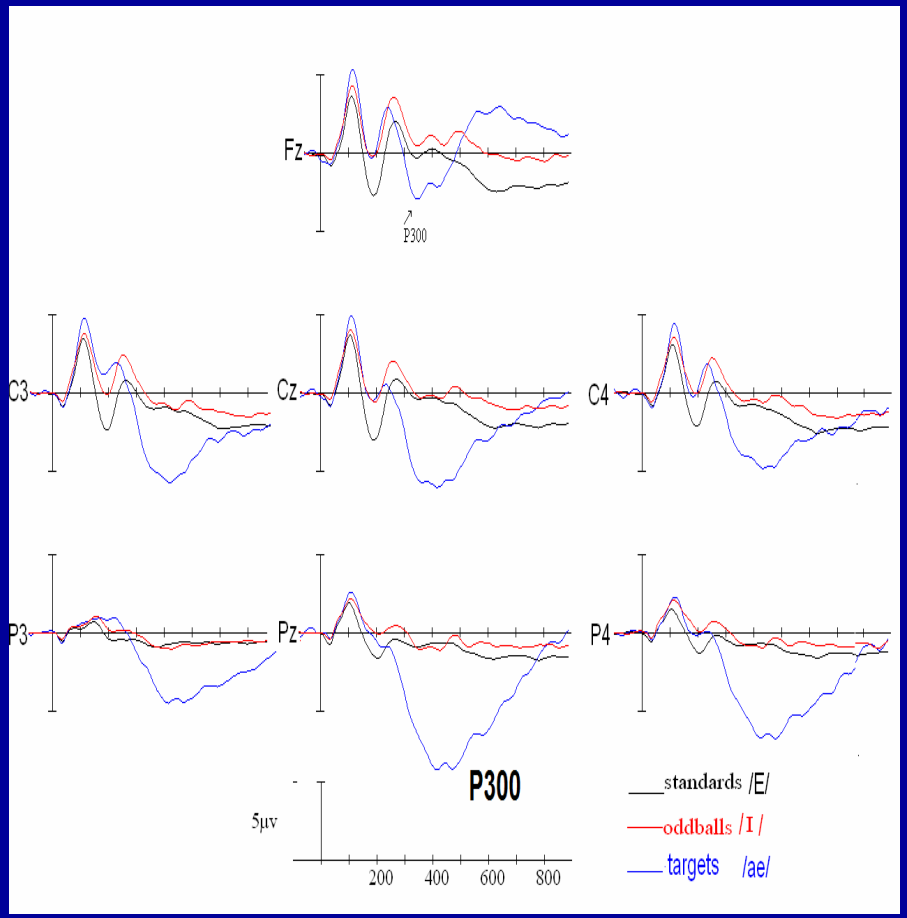


Frenck-Mestre, Meunier et al., 2005

P300 response to English contrast /E/ - /I/: native English vs. native French



L1 American-English



L1 southern French

Frenck-Mestre, Meunier et al., 2005

Conclusions from Frenck-Mestre et al. 2005

- Native English speakers show both discrimination and categorization of L1 vowels.
  - Target vowel [ae] produced both an N100 response and robust P300 in comparison to standard [E]
  - Oddball [**I**], unattended, produced an increase in N100 and small P300 in comparison to standard [E]
- Native French, “novice” in English, show initial discrimination (N100) but categorization of only attended vowel.
  - Graded N100, response corresponding to difference in F1 F2 values: [ae] > [**I**] > [E]
  - Target vowel [ae] produced robust P300 (categorized differently)
  - Oddball [**I**], unattended, produced only an increase in N100.
- Native L1 speakers showed “automatic” categorization of all L1 vowels: “irrepressible P3 response” (see FBI work ☺)
- Non-natives show only initial discrimination. Subsequent categorization is only observed if task-relevant (or if two-category contrast).

What about LATE BILINGUALS? Behavioral and ERP evidence of L2 vowel categorization in late learners

- Participants
  - Advanced L2 English, native French speakers,
    - All studying to be English instructors (CAPES)
    - All had been immersed in L2 for 6 mo – 2 years.
  - Native English speakers (new participants)
  - Native French speakers (new participants) « novice »secondary-school English

Vowel categorisation grid (10 vowels x 4 exemplars x 4 speakers (2 male, 2 female) x 3 languages) : 20+ participants per native group

1		X								
	heed	head	who'd	hid	hood	had	hut	hate	hot	hoed
2				X						
	heed	head	who'd	hid	hood	had	hut	hate	hot	hoed
3	X									
	heed	head	who'd	hid	hood	had	hut	hate	hot	hoed
4					X					
	heed	head	who'd	hid	hood	had	hut	hate	hot	hoed
5						X				
	heed	head	who'd	hid	hood	had	hut	hate	hot	hoed

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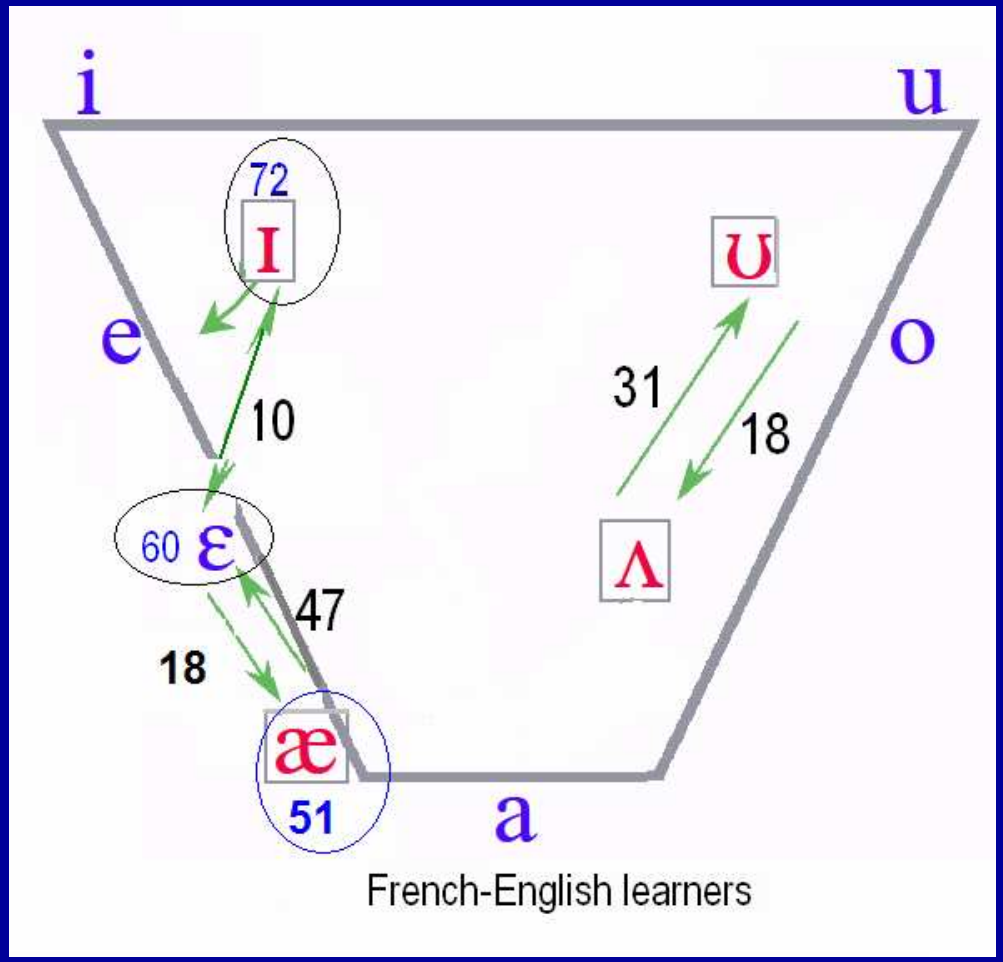
Assignment of American English (AE) vowels to AE categories by French L,1 late learners of English



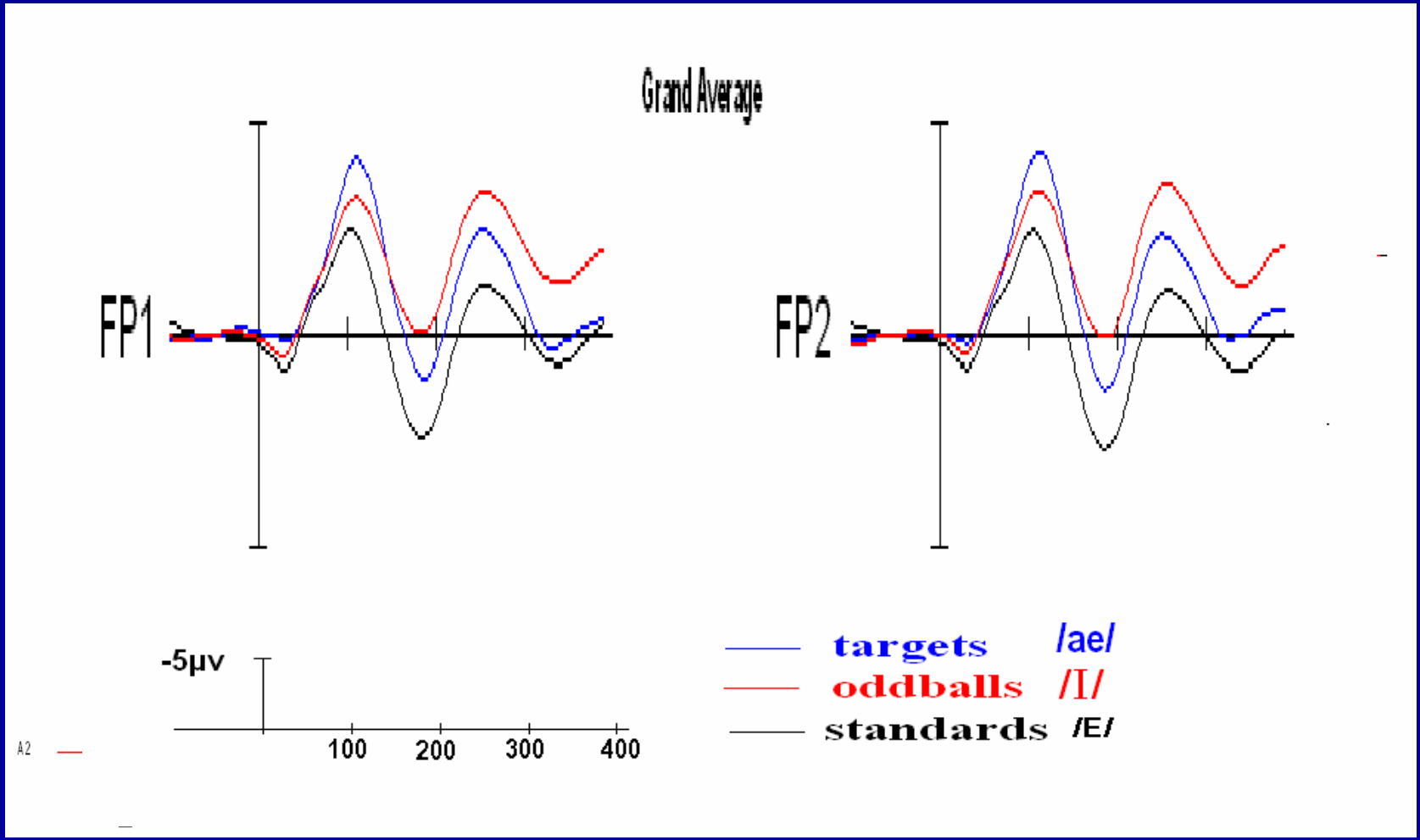
Peri, Frenck-Mestre et al., 2007

Second ERP study of contrast /**I**/ - /E/

for native A-English native French, French-English L2

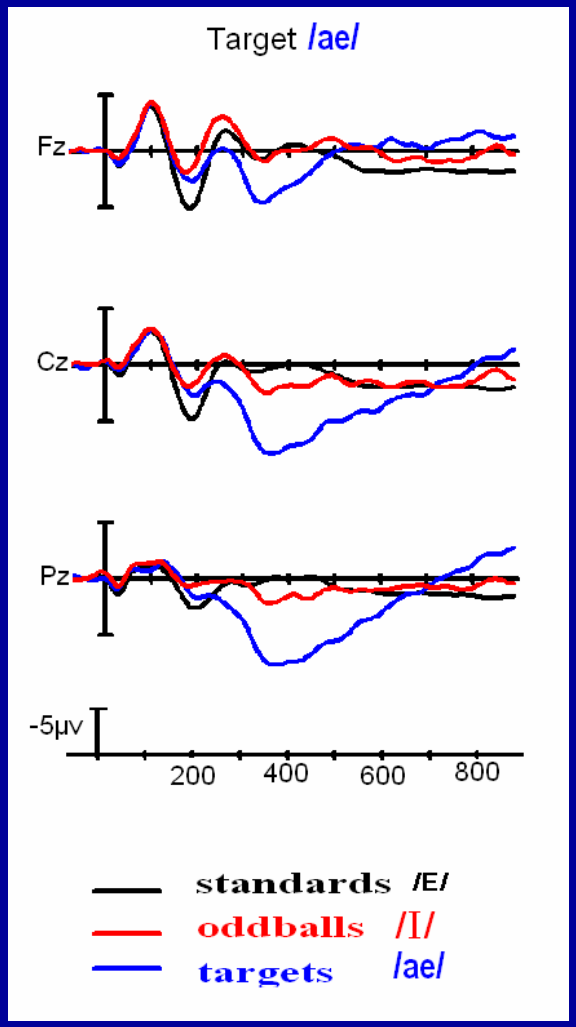
- Participants:
  - Native American-English
  - Native French, with only secondary school English
  - Native French, advanced L2 English, 1 year abroad, « CAPES »
- Methode : Same as experiment 1
  - 3 stimulus oddball task, ERP recording (32 channels)
- Stimuli : Same as experiment 1 except for target probability
  - Standard /E/ 82%
  - Target /ae/ 10%
  - Deviant /**I**/ 15%
- Task : Same as experiment 1
  - mentally count target /ae/ (give count at ¼, ½, ¾, end)
  - not informed about inclusion of deviant /**I**/
- ERP signatures of interest:
  - N100 (acoustic discrimination)
  - N2-P3 : conscious categorisation: Deviant /**I**/ is of greatest interest

N100: graded response to AE vowels: larger physical distance (Bark) = greater N1 amplitude

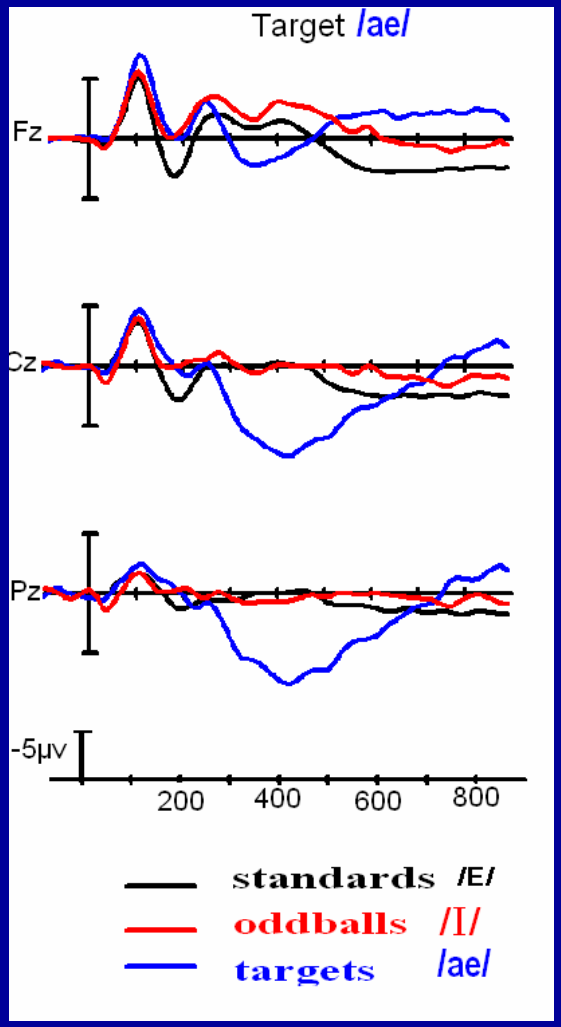


Significant effect of vowel at frontal sites: **ae > I > E**, no interaction with group (F<1)

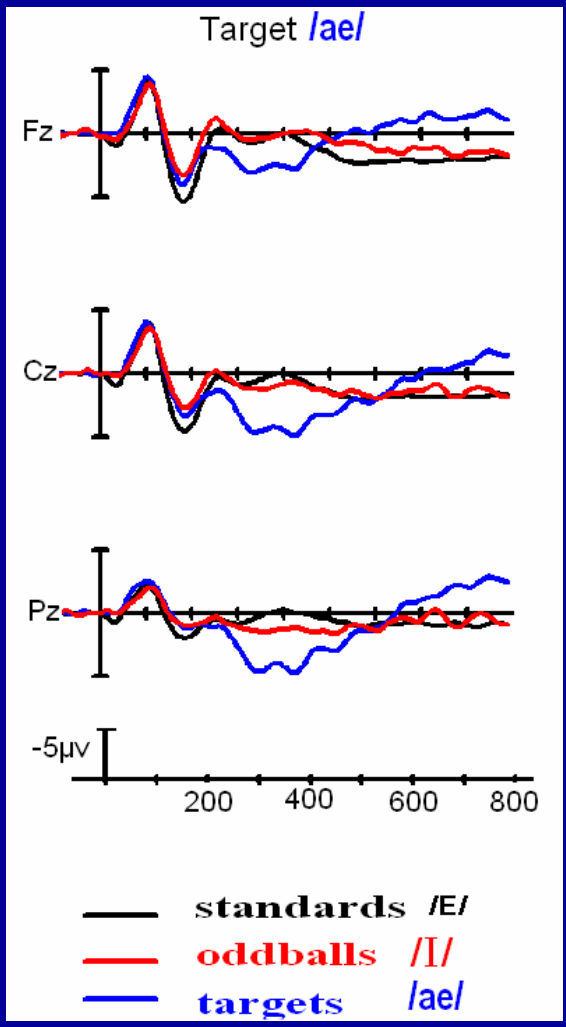
P300 response to unattended (oddball) [I] as a function of participant group



Native English speakers



French L1, monolingual



French L1- English L2

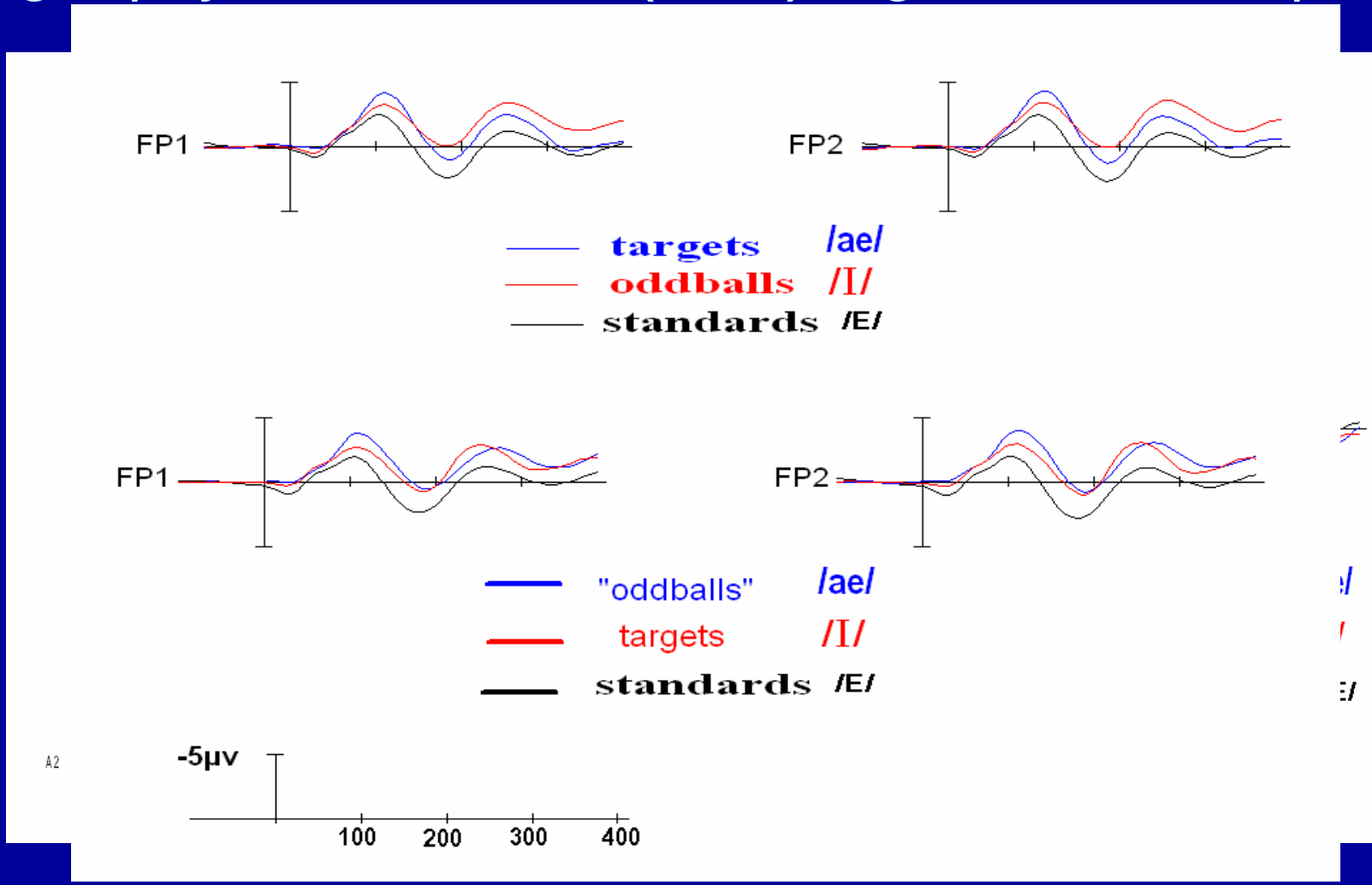
Conclusions from ERP experiment 2, of second study

- Replication of results of first ERP study
  - N100 amplitude varied as a function of physical (spectral) difference between vowels, for all speakers
  - P300, i.e. categorization, of unattended vowel if native contrast
- Evidence of new L2 category for late French-English « bilinguals »
  - P300, i.e. categorization, of unattended vowel [ɪ] against background [E]
  - Response nonetheless limited, smaller than for native speakers
  - P300 to target [ae] also somewhat reduced
- So, we're done, right?
- Nooo, what if we orient attention to [ɪ] ?

ERP experiment 3
further ERP evidence of L2 categorization

- Participants:
  - Same as in experiment 2
    - (native English, French, L1 French- proficient L2 English)
- Methode : Same as in experiment 2
  - 3 stimulus oddball task, ERP recording (32 channels)
- Stimuli : Same as in experiment 2: But roles inversed for target and deviant vowels. Probability held constant
  - Standard /E/ 82%
  - Target / **I** / 15%
  - Deviant / ae / 10%
- Task : mentally count target / **I** /
  - (give count at ¼, ½, ¾, end)

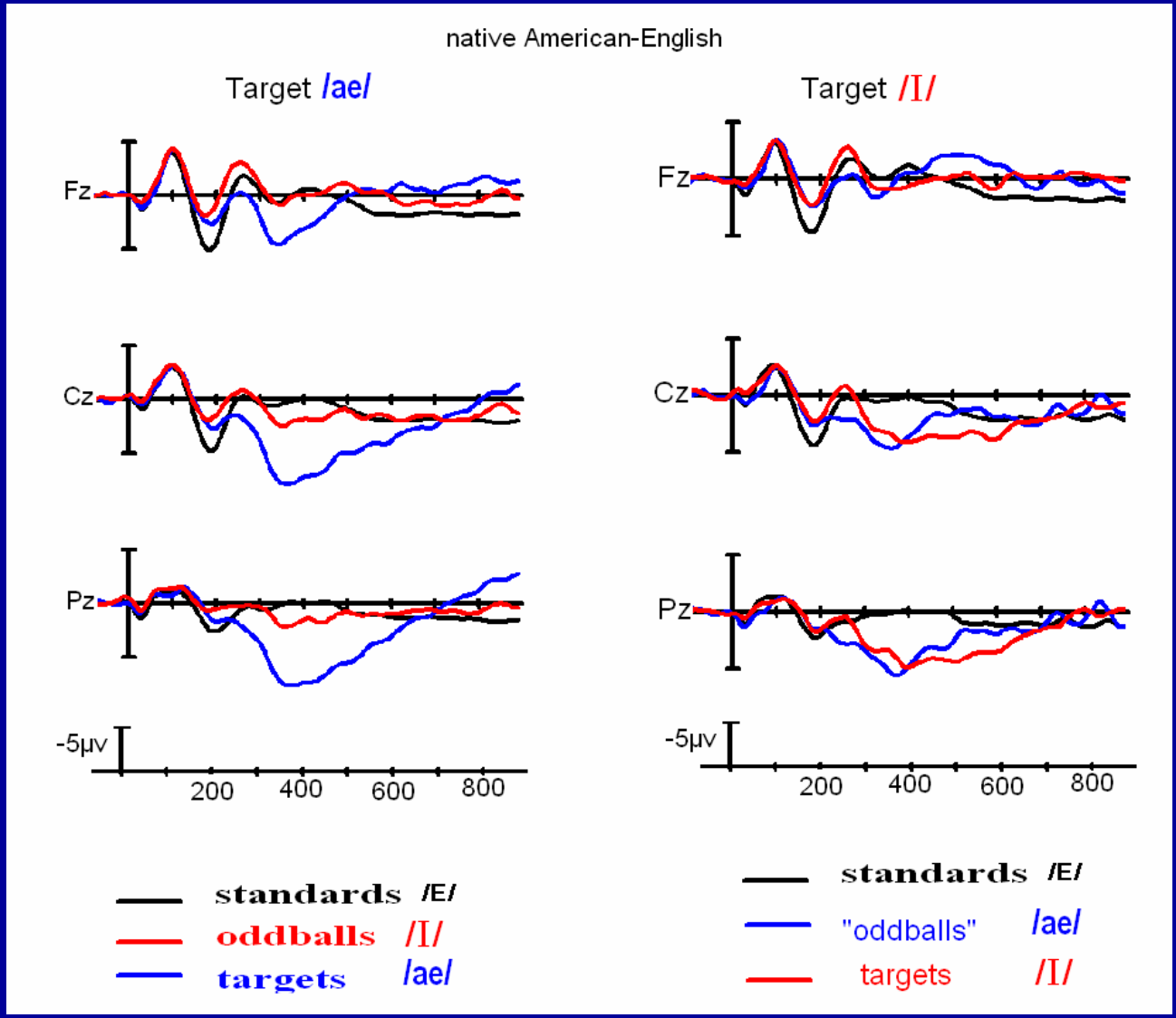
N100: graded response to AE vowels: larger physical distance (Bark) = greater N1 amplitude



Significant effect of vowel at frontal sites: **ae > I > E**, no interaction with group (F<1)

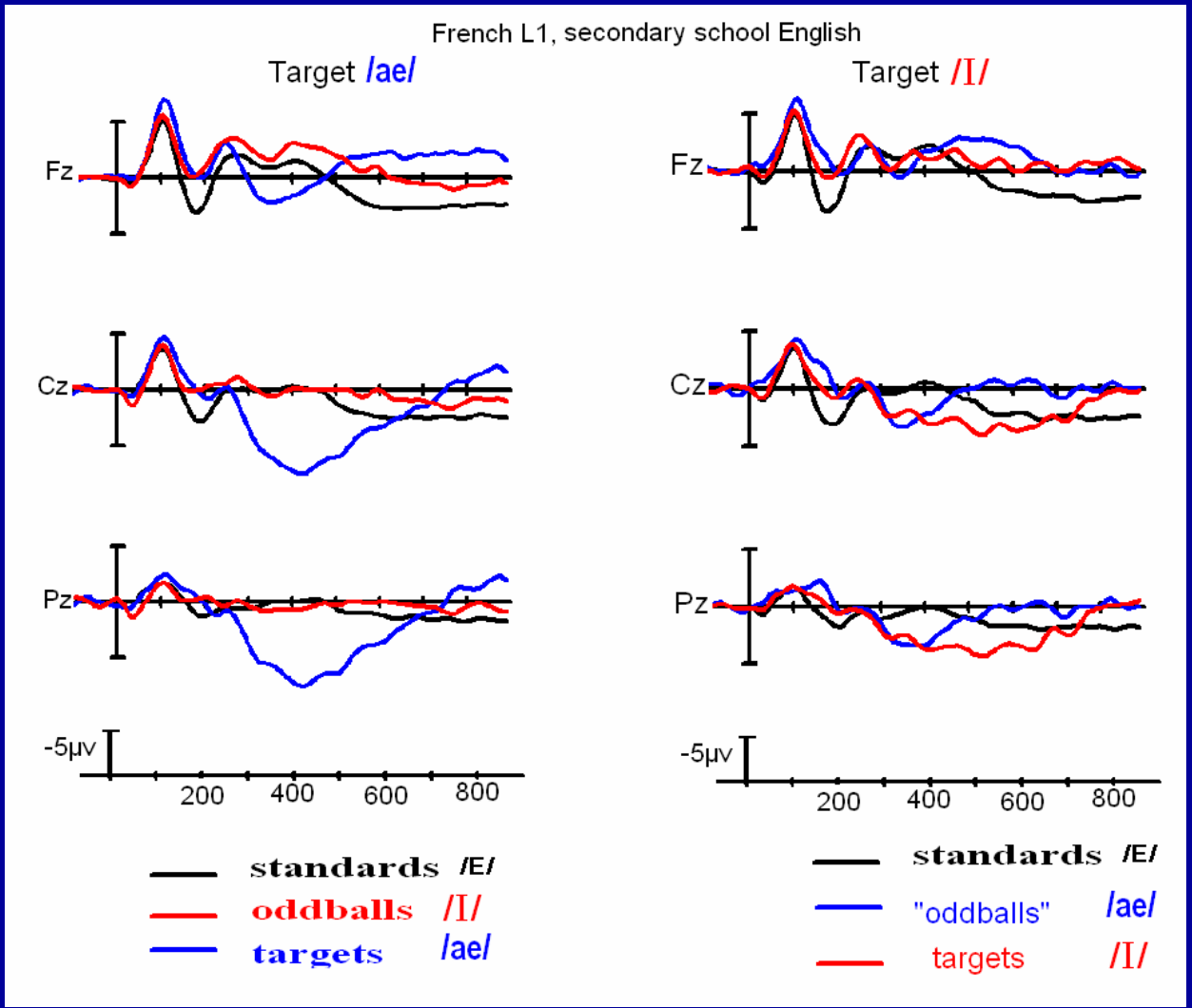
No interaction with task (target [ae] vs. target [I])

P300 response to [I] as a function of task



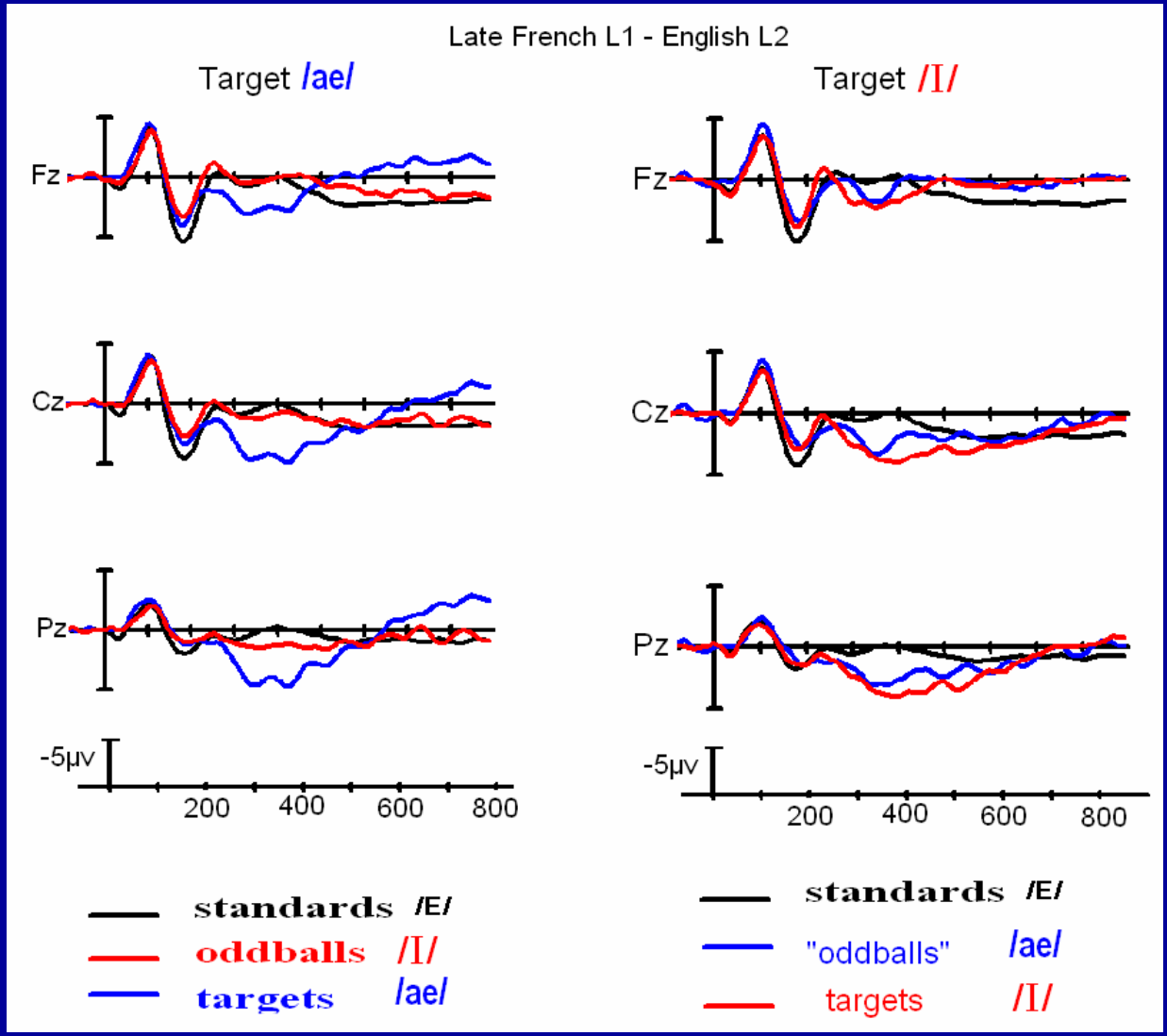
Significant increase in P3 to target [I], significant reduction in P3 to [ae]

P300 response to [I] as a function of task



Significant P3 increase to target [I], significant reduction in P3 to [ae]

P300 response to [I] as a function of task



Significant P3 increase to target [I], NO significant reduction in P3 to [ae]

Summary of results

- Across both experiments, the N100 response varied as a function of the acoustic difference between vowels, independent of task demands or linguistic capacities.
- Conscious categorization of vowels, as revealed by P300, was both task dependent and linguistically dependent.
  - For native English: even when unattended, all native vowels were categorized; P3 larger to target.
  - For native French: only task-relevant non-native vowels were consciously categorized: switching attention caused a significant P3 amplitude change.
  - For L1 French – L2 English: even when unattended, all non-native vowels were categorized, however, when task demands switched, the P3 amplitude did not decrease to « unattended » non-native vowels. Evidence of discrimination difficulty, still « unstable » formation of L2 categories.

Conclusions

- Our results corroborate many others (behavioral and ERP), showing that
  - L2 categories can be established
  - These categories can be automatically activated
  - Yet, they still differ from L1

- Important to note that our participants were still actively using their L1 and as much (or more) as their L2.
- Much more variability in the L2 learner group than in either of the « monolingual » groups

- So – half-empty or half-full?
  - « Even assuming that the speech perception system remains fully plastic after the L1 sound system has been established, it is probably unreasonable to suppose that early learners' perception of L2 vowels could ever be identical to that of L2 native speakers. » (Flege, 2006)

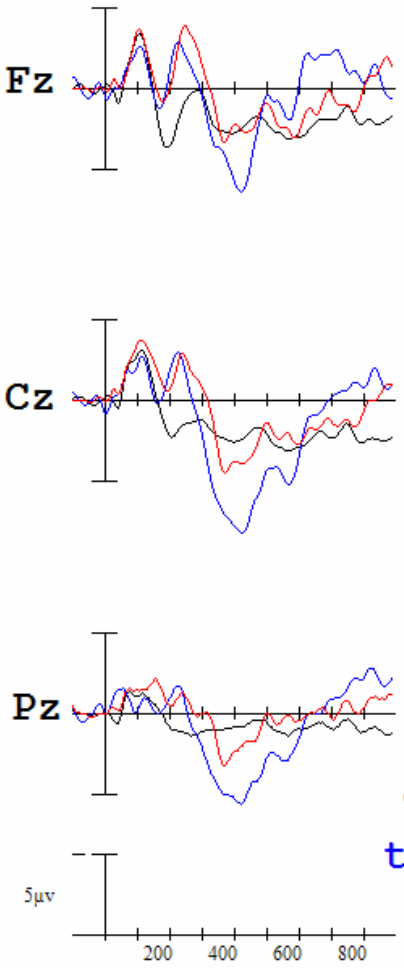
Merci de votre attention ☺

- Collaborators:
  - Christine Meunier, Robert Espesser, Pauline Peri (Laboratoire Parole et Langage)
  - Kirk Daffner (Brigham & Women's, Harvard)
  - Phil Holcomb (Neurocognition lab, Tufts)
  - Martine Le Besnerais (Universidad Autonoma de Barcelona)

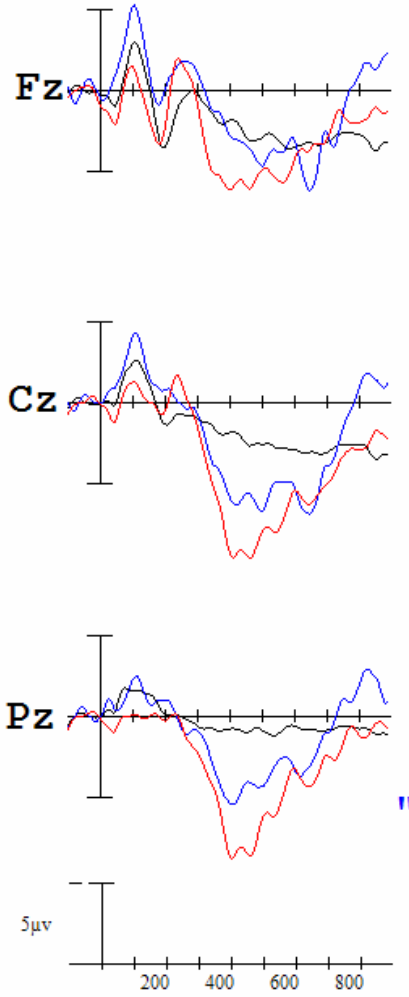
Difficulties in perceiving “non-native“ contrasts in Early/simultaneous bilinguals Behavioral evidence

- Catalan-Spanish both learned before age 4, but L1 can be dominant until schooling.
  - For the Catalan contrast [ɛ] –[e], Spanish-dominant early bilinguals
    - difficulty discriminating isolated vowels (Pallier et al., 1997)
    - repetition priming in LDT for minimal pairs (Pallier et al, 2001)
    - Difficulty discriminating words/nonwords (Sebastian-Galles et al., 2005)
  - Even for Spanish-dominant who have established Catalan contrasts [ɛ] –[e], [o] - [ɔ], [ʃ] - [ʒ], [s]- [z]
    - need more auditory information to identify minimal pairs (non-words) (Sebastian-Galles & Soto-Faraco, 1999).
  - L1 shapes the perceptual system at early stages of development in such a way that it will determine the perception of non-native phonemic contrasts,
    - even if there is extensive and early exposure to a second language
    - even for simultaneous bilinguals there appears to be 1 dominant system.

You can’t fool a P3b…



oddball /I/
targets /ae/

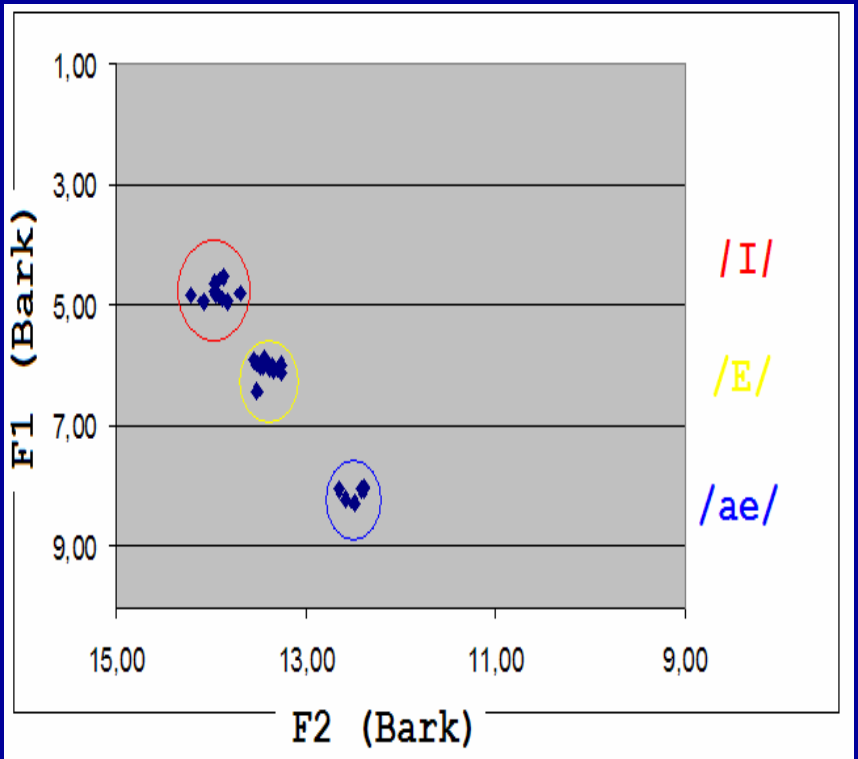


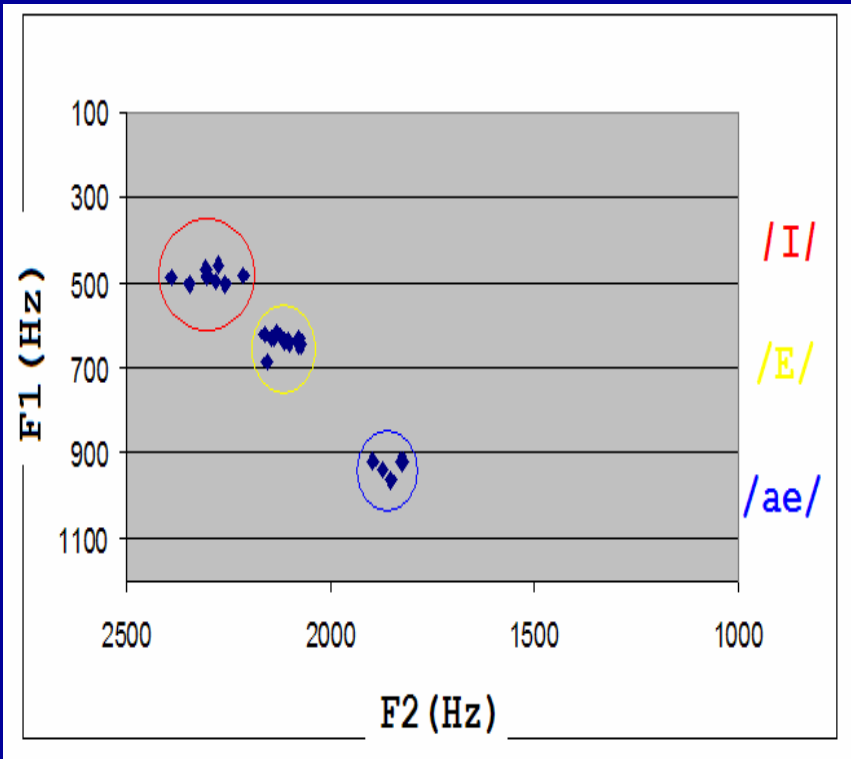
"oddball" /ae/
targets /I/

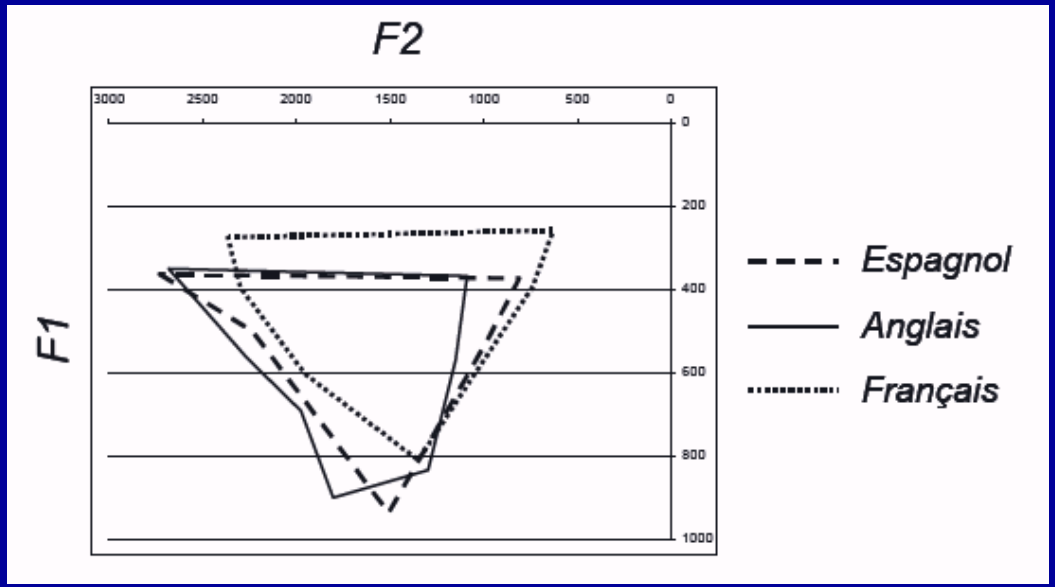
ERP response of a single participant (late French-English bilingual)

/**I**/ = 15% for all conditions, /ae/ = 10% for all conditions

Distances between vowels






F2
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1500
1000
500
0
F1
0
200
400
600
800
1000
Espagnol
Anglais
Français