Empirical methods in L2 phonology research

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• Overall introduction to L2 phonology research and speech perception in L2 learners
  – Main questions: What is L2 phonology?
  – Why focus on speech perception?
• Methodological questions
  – Behavioral methods to investigate non-native/L2 speech perception and the form of phonological representations in the mental lexicon
  – Introduction to neuroimaging methods
• Conclusions, discussion, questions
FOREIGN ACCENT AND L2 PHONOLOGY
A very old topic in the classical literature:

• “Gilead then cut Ephraim off from the fords of the Jordan, and whenever Ephraimite fugitives said, 'Let me cross,' the men of Gilead would ask, 'Are you an Ephraimite?' If he said, 'No,' they then said, 'Very well, say "Shibboleth".'

• If anyone said, "Sibboleth" because he could not pronounce it, then they would seize him and kill him by the fords of the Jordan. Forty-two thousand Ephraimites fell on this occasion.”

  [Judges, 12: 5–6. NJB]
Second Language Phonology

• The difficulties of mastering the processing of a non-native language have always attracted human attention.

• Yet it has not been until quite recently (60’s / 70’s) that researchers have begun to understand the basic sensory, perceptual, and linguistic mechanisms that operate at the base of this phenomenon.

• The most central question of L2 Phonology is: "how does the phonological system of L2 learners look like?"
Experimental method

• The first 2 things to know are
  ➢ How does the target-language phonological system look like?
  ➢ How does the L1 phonological system look like?

• Then, we can compare each of them to the developing phonological system of the learner (L2 or *Interlanguage* system) and see how they are different ...or not...

For example:
Target = English
L1 = Spanish

We need to know
1) How does English phonology works? (for NS)
2) How does Spanish phonology works? (for NS)
3) What do the learners do compared to each of them?
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3) What do the learners do compared to each of them?

We cannot simply start/stop with the question: “What do the learners do?”
What can we do to discover the structure of a phonological system? Can we simply take a grammar book and read it?

- Language ability is represented in the mind
- It is a cognitive system, a “knowledge” that we learn very early in life; part of it is innate
- Phonology also is represented in our minds:
  - Phonological system of the first language
  - And...... Maybe.... Of the second language

- How can we discover something that is in the mind?
Some techniques

• Can we ask people what they know about phonology?
  – Try and see.... (haha!)

• Can we analyze their productions?
  – Yes

• We can also perform laboratory experiments and measure their perceptual abilities or their processing abilities

  ➢ Psycholinguistics and Laboratory Phonology
Foreign accent and L2 phonology

Why not “simply” analyze learners’ productions in order to know what their L2 phonological system is like?

• In fact, this type of inference from productions has been done for quite a long time...

• foreign accent is the most audible consequence of Second Language Phonology (or the lack of it)
  – Non-native production of speech, due to non-target realization at different levels of phonetic implementation: Segments, Phonotactics, Phonological Processes and coarticulation, Prosody (Suprasegmentals), etc....

• As such, it is a good measure of overall level of phonological acquisition
Second Language Phonology is not only foreign accent

- But it is dangerous to think that the analysis of foreign accent can reveal the L2 phonological system
- Production is not an exact mirror image of the processing system!
  - One example: Children! They produce very few words until 18-24 months... Yet, their entire phonological system is in place and they can understand their L1 long before that!
  - Another example: certain sounds are difficult to produce, yet people can perceive them very well
  - The opposite is true too: People can imitate things without being able to perceive them

- Analyzing productions is not sufficient to understand the mechanisms of processing in L2!
Let’s take another example

• The influence of the L1-System
  – it is not only a production problem
  – it can be much more complicated
L2 phonology: it can be dangerous!

www.youtube.com/watch?v=yR0lWICH3rY

© Berlitz
What happened?

- This case is not merely a problem in the *production* of /s/ vs. /th/ sounds. It is foremost a problem in *perception*, in the mental representation of these sounds.
- Upon hearing *sinking*, this young man activates *thinking* in his lexicon. Why?
  - German has no /th/ sound, and so this listener/learner mapped it onto one similar category in his own inventory: He has /s/ available, and so he applies this /s/ category to both [s] and [θ]. Both English sounds are merged into one category.
  - This perceptual assimilation to a single category provides the basis for building and accessing his lexicon.
  - The word *thinking* seems to be inappropriately represented in the lexicon, so that the sound sequence *[sinkin]* activates straightforwardly the *thinking* entry.
- He formulates an answer that is conceptually and grammatically appropriate to a *thinking* lexical entry. This entry might have the same form for both *thinking* and *sinking* (while still being connected to two *different concepts*, but unfortunately, he chose the wrong one)
  - [  he might have additional pragmatic problems....]
- His pronunciation of the lexical entry he decided to utter is also reflecting the merging of /th/ and /s/ sounds in one category
Many sources for “L2-phonological problems”...

• **The role of perception**
  – Language specific perception affects every phonological level and is responsible for various transfer phenomena: our competence in L1 acts as a *filter* for perception of L2

• **The role of representations**
  – Language specific perception is in turn responsible for wrong representations of L2-words which might result in deviant pronunciation of L2

• **The role of production**
  – Even if some sounds or properties are correctly perceived and represented, L1 competence can also act as a *filter* at this stage, and influence the way articulatory plans are established or realized.
Many sources for “L2-phonological problems”...

• The role of perception
  Language specific perception affects every phonological level and is responsible for various transfer phenomena: our competence in L1 acts as a filter for perception of L2.
  Merged lexical entries, several entries instead of one, wrong phonemic representation, wrong segmentation...

• The role of representations
  Specific perception is in turn responsible for wrong representations of L2-words which might result in deviant pronunciation of L2.
  Even if we know a difference, we do not manage to articulate it correctly for L2 (e.g. trill R, retroflex stops or clicks).

• The role of production
  Even if some sounds or properties are correctly represented, L1 competence can also act as a filter at this stage, and influence the way articulatory plans are established or realized.

We “hear” absent segments, we miss others that are there, we misperceive segments as different ones, we ignore dimensions that are not relevant in our L1 phonology...
SPEECH PERCEPTION IN L2 LEARNERS
Difficulties in phonetic perception

• As source of foreign accent
• What is the source of those difficulties in the first place?
  – Less effective recognition of the identity of some sounds ("phonetic segments")
  – Miscategorizations
  – Interference between languages due to the different number or characteristics of phonetic categories
  – ...

Development of Language-Specific Listening

• At birth, mechanisms to perceive speech in linguistically relevant dimensions are in place
  – Categorical perception
  – The boundaries between categories are not innate and need to be acquired during the first year (Lasky et al. 1975)

• Most L1 categories and most of other phonological dimensions are acquired by babies around 9 months

• The fine-tuning to L1 categories is complete around the first birthday (Werker & Tees 1984)
Language-specific perception

• These language-specific patterns of perception acquired in infancy are not readily modified in adulthood
  – => Adults experience difficulty perceiving non-native consonant and vowel contrasts (and many other non-native dimensions...)

• It affects the perception of various phonological units:
  – Segmental categories (Pallier et al. 1997, 2001; Strange et al.; Polka et al; Best et al....)
  – Phonotactics (Dupoux, Kakehi, Hirose et al. 1999)
  – Suprasegmental properties (Dupoux, Pallier, Sebastian, Mehler, 1997)
  – Phonological processes (Darcy, 2006, (e.g. Darcy, Peperkamp & Dupoux, 2007)

• Pattern of influence depends on L1

• Language-specific perception is usually very hard to modify (little plasticity) for a second language, because processing is very early, mostly unconscious (automatic)

See Sebastian-Gallés 2005
Polivanov, 1931, already saw it...

• « Le phonème et les autres représentations phonologiques élémentaires de notre langue maternelle (...) se trouvent si étroitement liées avec notre activité perceptive que, même en percevant des mots (ou phrases) d’une langue avec un système phonologique tout différent, nous sommes enclins à décomposer ces mots en des représentations phonologiques propres à notre langue maternelle »

  ➢ Yevgeni D. Polivanov (1931) La perception des sons d'une langue étrangère. Travaux du Cercle linguistique de Prague.

• [The phoneme and the other phonemic representations for our native language (...) are so intricately linked to our perceptual activity that even when we hear words (or sentences) from a language with an utterly different phonemic system, we tend to analyze these words in terms of our native language phonemic representations]
OVERVIEW OF SOME METHODS

How do we test L2 speech perception?

Overview of some perception tasks

• Test for phonetic/phonological knowledge
  – Identification/labeling
  – Categorization: AXB, ABX, Oddball / Oddity...
  – Phoneme monitoring, word spotting, syllable detection

Depending on specific variables of your design, this may also test for lower level phonetic perception

• Test for phonetic perception
  – Discrimination: AX (Same-Different)
  – Cross-language mapping

• Test for indexical properties of speech
  – Accentedness or comprehensibility judgments
  – Dialect detection or classification...

• Test for lexical representations
  – Lexical Decision (With or without repetition priming)
  – Gating
  – Priming (Form priming, semantic priming, masked priming)
  – Word recognition in noise
  – Eye-tracking: lexical activation
Phonetic perception

CROSS-LANGUAGE MAPPING
Relationship between L1 and L2 categories

• Best‘s Perceptual assimilation model (Best, 1995) tries to predict perceptual difficulties

• Flege‘s speech learning model (Flege, 1995): importance of perceptual relationships between L1 and L2 categories in terms of equivalence classification
  – Is one category in L2 equivalent to a category in L1?


Central concept: Perceptual assimilation

- “when listening to an unfamiliar nonnative phone (phonetic segment), naïve listeners are likely, due to their native language experience, to perceptually *assimilate* the nonnative phone to the most articulatorily-similar native phoneme” (Best, 1995, p. 22)

- Assimilation pattern (for each phone in a contrasting nonnative pair) will predict identification and discrimination accuracy
  - Mapped onto 2 different categories, discrimination is possible
  - Mapped onto the same category, discrimination will be more difficult
Cross-language perceptual mapping

- Examines the patterns of perceptual assimilation of L2 vowels to L1 categories
- Predict perceptual difficulties
- Is an efficient way to select the contrasts you want to test in a discrimination/ categorization experiment
  - Narrowing down the focus, avoiding to test all possible contrast pairings
Strange et al. 1998

• How do Japanese listeners “map” the 11 non-rhotic American English vowels onto their 5 vowel categories?
  – What is the importance of length?
• Do they use phonetic similarity?
  – > Role of different speech contexts (isolation vs. sentences)

Segmental Inventory of Japanese and English (vowels, simplified)

http://www.asian-efl-journal.com/december_04_KO.php
Methods

• „hVb“ in sentence, or in disyllables
  – „hVba“ vs. „I say the hVb on the tape“
• Presented for categorization and goodness judgement

• Four male native speakers of American English produced the stimuli
• A total of 264 stimuli was employed in the study: 11 vowels x 3 tokens x 2 conditions x 4 speakers
• 24 Japanese listeners with minimal English knowledge categorized and rated the stimuli
Mapping and goodness judgement

- After the first presentation, the subject categorized the /hV/ target syllable as “most similar” to 1 of 18 Japanese response alternatives, by selecting one of 18 katakana characters displayed on the computer screen.
  - (Response alternatives were selected based on a preliminary open-transcription test by several Japanese listeners.)
- Then, the same stimulus was repeated and the subject rated its “goodness” as an instance of the chosen response alternative on a scale from 1 to 7; the endpoints were labeled “Japanese-like” (7) and “not Japanese-like” (1)
### Table I. Spectral Assimilation Patterns

Categorization responses, expressed as percentages of total responses summed over speakers and listeners within Disyllable (A) and Sentence (B) conditions.

<table>
<thead>
<tr>
<th>A. Disyllable</th>
<th>Japanese response categories</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High front i, ii</td>
</tr>
<tr>
<td>iː</td>
<td>99</td>
</tr>
<tr>
<td>i</td>
<td>59</td>
</tr>
<tr>
<td>ɛ</td>
<td>9</td>
</tr>
<tr>
<td>ɛ̃</td>
<td>1</td>
</tr>
<tr>
<td>æː</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>ɑː</td>
<td></td>
</tr>
<tr>
<td>Λ</td>
<td></td>
</tr>
<tr>
<td>ɔː</td>
<td></td>
</tr>
<tr>
<td>ɒː</td>
<td></td>
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<tr>
<td>u</td>
<td></td>
</tr>
<tr>
<td>uː</td>
<td></td>
</tr>
<tr>
<td>uː</td>
<td></td>
</tr>
</tbody>
</table>
A display example
A display example

Click here to play the last sound again
Conclusions

• The precise phonetic characteristics of each sound determines the exact pattern of perceptual assimilation

• For categories that do not correspond to any Japanese/L1 category, the pattern of assimilation is more distributed and goodness ratings are less high
Discussion

• Variations of the task
  – Factors such as context (sentence vs. disyllable), lexical status, stress pattern, proficiency, etc. have a non-negligible effect on perceptual assimilation and categorization

• Issues with this technique
  – Orthographic labels often need to be used
    • Can strongly interfere with perception!!
  – Mapping is not always equal to categorizing
PHONOLOGICAL KNOWLEDGE CATEGORIZATION (ABX AND CO.)
Methods

• AXB (or ABX) is the most common paradigm to study categorical perception
  – Listeners have to classify one sound (X) according to a previous (A) or a following one (B)
  – All three stimuli are (slightly) different
    • 3 different voices or 3 different tokens
    • this allows to tap the phonetic category level, and not only the low level auditory acoustic matching level

Polka 1995; Højen & Flege 2006
AXB (ABX) and categorization

**Speeded ABX task**

- **S1:** A or B
- **S2:** B or A
- **S3:** A or B

**Response:** A or B

- **Female voice at S1:**
- **Male voice at S2:**
- **Female voice at S3:**
Participants and stimuli

**L2 French**

- Front/Back rounded vowels
  - [front rounded] \[œ\] [y]
  - [back rounded] \[ɔ\] [u]

**L1 English**

- **Intermediate** [max. 4 semesters
  N = 19]
- **Advanced** [> 6 months in
  France, 8 semesters, N = 19]

- **French Native Speakers**
  [N = 8]

- **L1 English (no French)**
  [N = 13]

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Darcy et al. (2012)
ABX

Stimuli

L2 French

Interaction between “group” and “condition”: more errors on the test conditions

Learners ≠ native speakers on test vowel pairs, but not on the control.

Intermediate and advanced groups are not significantly different on any vowel pair ($p > .1$ in all cases).

Relatively accurate perception of /u/-/y/ (around 10% error for either L2 group)

All groups have higher errors on the mid vowel contrast
ABX task

Response: A or B

Identification

S1  S2  S3  S4  S5
VOT: 0  10  20  50  60
“B” or “P” or “P” or “P” or “P”

Identification (labeling)

Discrimination (measured)

Percent / % Correct

VOT (msec)
## Two methods to test L2 categories

### Identification

- Involves categorization
  - How (ambiguous) sounds are categorized = attributed to one category
- Involves attributing a label of some kind (= metalinguistic awareness), as well as the ability to distinguish between both A and B
- Usually entails a 2 alternative forced choice
  - E.g.: you hear [X] .... Was this *pin* or *pen*? Was this “p” or “b”? ...
- Often done together with a discrimination task \(\Rightarrow\) identification predicts discrimination
  - Same or different, or AX task (and sometimes also ABX)

### AXB/ABX

- Also can involve a categorization decision for X (as A or B)
  - **if:** There is some inherent variability in the stimuli \(\Rightarrow\) The more variability, the more phonological and the less acoustic the task is
  - [with physically different tokens, e.g. via different voices]
  - **if:** Inter-Stimulus-Interval is not too short
  - Does **not need explicit labeling** because one hears all three tokens
    - Pattern-matching and comparison between things
- Requires to keep items in memory
- Four combinations (ABX): **ABA, ABB, BAA, BAB** [bias issues]

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**Note:**

- The text includes examples of how to use these methods, such as distinguishing between ambiguous sounds like “pin” or “pen.”
- The AXB/ABX method is particularly useful when dealing with variability in stimuli, as it can help in distinguishing between phonological and acoustic features.
- The choice of whether to use discrimination tasks or identification tasks depends on the specific research question and the characteristics of the stimuli.
LEXICAL DECISION

<table>
<thead>
<tr>
<th>Language</th>
</tr>
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<tbody>
<tr>
<td>English</td>
</tr>
<tr>
<td>Japanese</td>
</tr>
<tr>
<td>German</td>
</tr>
<tr>
<td>Spanish</td>
</tr>
</tbody>
</table>

Is it a real word? Yes/No
Lexical Decision

• Speeded classification of spoken words and nonwords
• It can reveal many aspects of lexical representations and lexical activation patterns
  – effects of word frequency
  – neighborhood effects (competitors)
  – effects of lexical analogies on non-word rejection time; effects of phonological structure (such as unlikely phonotactics...)
• Often combined with priming
  – Preactivation of a word yields faster RT the next time you encounter this word : Repetition priming
  – Faster decision for a word which was previously activated by a semantically related word → semantic priming (honey → faster on bee)
One example


- (p. 695) “Stress ‘deafness’ emerges here as a robust processing limitation, which cannot be eliminated with a significant exposure to a language with contrastive stress”
  - French L2-learners of Spanish + Spanish native speakers
  - Lexical decision task for Spanish words and non-words

Lexical Decision

górro is a word (‘hat’)

gorró is not

As a control condition, they used word–nonword minimal pairs differing by a single phoneme

Dupoux et al., 2008, Table 6
How does this task work?

• What does it “say” ...
• What does it show?
• These results demonstrate that the stress ‘deafness’ effect observed with the sequence recall task is not limited to the encoding of stress in short-term memory but extends to lexical access.

• In other words, the suprasegmental distinction that is pertinent to the encoding of words in Spanish barely seems to be available to French learners of Spanish, even to those who have quite a good mastery of the Spanish lexicon.

• This is consistent with the hypothesis that the encoding of stress remains by and large unavailable to French learners of Spanish, at least as far as usage in on-line tasks is concerned. (p. 699-700)
PRIMING
Basic procedure example

• Lexical Decision

1000 ms

300 ms

1500 ms

REAL WORD? (yes/no)
Principle of Priming

• Pre-activation coming from one word (spreading to other words) creates faster reaction on a paired word
  – Participants are presented with a target, to which a response is required, preceded by a prime.

• Reaction time compared to a baseline
  – a condition where there is no link between two words

• Priming needs a task that can measure reaction times and error rates
  – Lexical decision, naming, stroop colour naming, identification in noise... etc.
Different kinds of priming

Depending on the relation chosen between the paired words

• Semantic priming (associate priming)

• Form priming
  – Direct (blank – plank)
  – Mediated (plank – white)
    • plank is form-related to blank which is semantically related to white

• Fragment priming

• Repetition priming

Depending on the modality of presentation of the stimuli

• Cross-modal priming
  – Prime is heard
  – Target is written

• Uni-modal priming
  – Both stimuli in one modality (auditory, print, etc...)

• Masked priming
  – when the prime word is so short that people don’t know they saw/heard it

• Long-term vs. Short-term priming
  – Depends on how much time between the prime and the target
Example of Form Priming

• Do embedded near-words enter the competition process as words for L2 learners?
  – *groof* is perceived as word (*groove*)
  – homophony in the lexicon, perhaps because *groove* is encoded as [gruf]
  – Would a sequence like „*big roof*“ prime the word *groove*?

• Comparison with L1 listeners

Experiment 1: Simple lexical decision

Fig. 1. Experiment 1: English and Dutch listeners’ percentage of “yes” responses to words and near-words.
Experiment 2: Cross-modal form priming

Materials

<table>
<thead>
<tr>
<th>Target word</th>
<th>Condition (prime)</th>
</tr>
</thead>
<tbody>
<tr>
<td>+V (groove)</td>
<td>Control (spend)</td>
</tr>
<tr>
<td></td>
<td>Match (groove)</td>
</tr>
<tr>
<td></td>
<td>Mismatch (groof)</td>
</tr>
<tr>
<td>-V (flight)</td>
<td>Control (care)</td>
</tr>
<tr>
<td></td>
<td>Match (flight)</td>
</tr>
<tr>
<td></td>
<td>Mismatch (flide)</td>
</tr>
</tbody>
</table>

Visual Targets

- GROOVE
- FLIGHT
Results: Experiment 2

English listeners: No difference between Control and Mismatch prime types > mismatch does not activate the word activated by the visual target.

Dutch listeners (L2-English): No difference between MATCH and Mismatch prime types > mismatch does activate the same word activated by the visual target, just as match does.
Conclusions

• “The pronunciation of near-words such as *groof* in real speech contexts such as *big roof* is just as capable of activating *groove* for a L2 listener as the isolated form *groof*. These contexts cause phantom word activation for L2 listeners, while L1 listeners experience no such effect.”
EYE-TRACKING
Tanenhaus et al., 1995

– Head-mounted eyetracking method
– On-line index of spoken language comprehension: records what objects listeners look at

**Fig. 1.** View showing a subject’s fixation (crosshairs) on an interlingual distractor (“marker,” upper left object) upon being instructed, in Russian, to pick up the stamp (“Poloji marku nije krestika”; the stamp is the lower right object).
“Look at the center”
“Pick up the can...”
As the target word unfolds in real time, both **candle** and **candy** are activated in parallel during monilingual language processing => shown by time spent fixating each picture.
Bilingual lexicon activation

• Technique allows to monitor the time course of lexical activation
  – target, competitor, distractors

• Bilinguals: Do they activate the 2 lexicons separately? Or in parallel? Can they inhibit the activation of an irrelevant lexicon?

• Difference between *late* and *early* bilinguals?
Marian & Spivey, 2003

• Is there some overlap in the processing of the two languages in bilinguals?
  – Spivey & Marian 1999: Phonological overlap
  – Russian English late bilinguals look at “marku” (stamp) in Russian but also at competitor “marker” (English word)
  – cross-linguistic cohort

• Spoken language activates both mental lexicons in parallel

• But one factor that has not been strongly controlled was the language mode → They might have been in an intermediate language mode
Better control of the mode

• Goals
  – Between-language competition from L1 into L2
  – Within language competition in L2
  – Simultaneous between- and within-language competition from L1 and L2 while processing L2

• Controlling for language mode
  – Strengthen a monolingual (L2) mode
  – No use of Russian (L1) at any point
  – Exclusively conducted in English (monolingual experimenters) and no mention of bilingual nature of study
  – Monolingual speaker recorded instructions and target words
Stimuli

- target object (English) car
- English competitor object card
  - (overlap between English name and English target name)
- Russian competitor object potato
  - Kartoschka (= ‘potato’: overlap between Russian name and English target name)

- more triplets:
  - gun – gum – gaika (‘nut’)
  - chess-set – chair – cherepakha (‘turtle’)
  - shovel – shark – sharik (‘balloon’)
  - etc.
**Fig. 1.** View showing a subject’s fixation (crosshairs) on an interlingual distractor (“marker,” upper left object) upon being instructed, in Russian, to pick up the stamp (“Poloji marku nije krestika”; the stamp is the lower right object).
Table 2. Percent of trials in which bilingual participants made eye movements to the competitor items and their corresponding fillers in between-language competition, within-language competition, and simultaneous competition trials in Experiment 1.

<table>
<thead>
<tr>
<th>Display</th>
<th>Fixations of between-language competitor</th>
<th>Fixations of within-language competitor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between-language competitor present</td>
<td>18%</td>
<td>n/a</td>
</tr>
<tr>
<td>Within-language competitor present</td>
<td>n/a</td>
<td>18%</td>
</tr>
<tr>
<td>Both competitors present</td>
<td>13%</td>
<td>19%</td>
</tr>
<tr>
<td>No competitor present; fixations of control filler object</td>
<td>7%</td>
<td></td>
</tr>
</tbody>
</table>

Fixations to control filler objects (% of trials) : 7%  
Fixations to within language competitor: 18%  
Fixations to between-language competitor : 18%  
When both competitors present  
  between language 13%  
  within language 19%
Results

• Show that bilinguals experience between-language competition from their L1 into L2, as well as within-language competition from L2
  – (like the native speakers of that L2)

• Increased amount of competition while processing language for bilinguals
  – They seemingly cannot inhibit their L1 to be activated while processing L2
NEURO-IMAGING STUDIES (AND LITTLE BRAIN INTRO)
Overview

• Why do we need brain imaging studies?
  – Some behavioral results that do not show any difference between L1 and L2 still might uncover some differences in brain responses, processing speed, or localization
  – Of course: techniques are still emerging, so not very precise nor very helpful with respect to, e.g., detailed processing steps
  – But if we uncover systematic, reproducible and robust brain response differences for behaviorally similar data, this might be a sign that we need more sensitive behavioral measures... ➔ more work to be done
Cerebral representation of language
ERP

- An **event-related potential** (ERP) (sometimes called “evoked potential”) is any measured brain response that is directly the result of a thought or perception. More formally, it is any **stereotyped electro-physiological** response to an internal or external stimulus.
- It is measured in microvolts μV (a millionth of a volt)
- ERPs are measured with electro-encephalography (EEG).

Can we see phonemes in the brain?

• Early exposure to phonemic contrasts shapes the brain responses to native contrasts: they are larger for native than for non-native ones.

• Typical brain response to contrast: change detection response:
  - The MMN

http://www.cbru.helsinki.fi/mismatch_negativity/mmn.html
Can we see phonemes in the brain?

• Early exposure to phonemic contrasts shapes the brain responses to native contrasts: they are larger for native than for non-native ones.

• Typical brain response to contrast: change detection response:
  – The MMN

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Can we see phonemes in the brain?

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http://www.cbru.helsinki.fi/mismatch_negativity/mmn.html
Mismatch Negativity

if there is no difference perceived between 2 sounds, there is no/a smaller MMN (the wave is flatter)

the bigger the (acoustic or perceived) change, the larger the MMN
Experimental Paradigm

3000 ms  600 ms  time

S1  S2  S3  S4

Ba Da  Ba Da  Ba Da  Ba Ba

Response to a change
Response to repetition
Näätänen et al. 1997

• Language specific response of the brain for phonemic contrasts

• Difference between Finnish and Estonian vowels
  – Finnish: /e/, /ö/, /o/ ...
  – Estonian: /e/, /ö/, /õ/, /o/ ...

## Finnish vowels

### Primary stressed position

<table>
<thead>
<tr>
<th>V/VV</th>
<th>single (short)</th>
<th>double (long)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i/iī</td>
<td><strong>sika</strong> 'pig'</td>
<td><strong>siika</strong> 'whitefish'</td>
</tr>
<tr>
<td>e/ee</td>
<td><strong>te</strong> 'you; pl.'</td>
<td><strong>tee</strong> 'tea'</td>
</tr>
<tr>
<td>y/yy</td>
<td><strong>ryppy</strong> 'wrinkle'</td>
<td><strong>ryppy</strong> 'pull, drink'</td>
</tr>
<tr>
<td>ĕ/ĕŏ</td>
<td><strong>tōtti</strong> 'prop' (techn.)</td>
<td><strong>tōtti</strong> 'horn' (colloq.)</td>
</tr>
<tr>
<td>ā/āă</td>
<td><strong>vārin</strong> 'color, gen.'</td>
<td><strong>vāarin</strong> 'wrongly'</td>
</tr>
<tr>
<td>a/aa</td>
<td><strong>varat</strong> 'funds'</td>
<td><strong>vaarat</strong> 'danger; pl.nom.'</td>
</tr>
<tr>
<td>o/oo</td>
<td><strong>polo</strong> 'poor'</td>
<td><strong>pooło</strong> 'polo'</td>
</tr>
<tr>
<td>u/uu</td>
<td><strong>puro</strong> 'brook'</td>
<td><strong>puuro</strong> 'porridge'</td>
</tr>
</tbody>
</table>

[Link to source](http://www.helsinki.fi/puhetieteet/projektit/Finnish_Phonetics/vokaaliesim_eng.htm)
## Estonian vowels

### Long and Short sounds

<table>
<thead>
<tr>
<th>Short</th>
<th>Long</th>
<th>Short</th>
<th>Long</th>
</tr>
</thead>
<tbody>
<tr>
<td>a/aa</td>
<td>sada</td>
<td>saada</td>
<td>võra</td>
</tr>
<tr>
<td>e/ee</td>
<td>keda</td>
<td>keeda</td>
<td>käsí</td>
</tr>
<tr>
<td>i/ií</td>
<td>kilu</td>
<td>kiilu</td>
<td>nöbi</td>
</tr>
<tr>
<td>o/oo</td>
<td>soni</td>
<td>sooni</td>
<td>müdin</td>
</tr>
<tr>
<td>u/uu</td>
<td>kuri</td>
<td>kuuri</td>
<td>müüdi</td>
</tr>
</tbody>
</table>

Vowels: õ, ü, ö
Materials

- 10 semi-synthesized vowels

Formant 1, 3 & 4: constant

Formant 2: modified to get the vowel quality

Used in a goodness rating and categorization task: press the corresponding button if you think it is a good exemplar
Behavioral data

Finns categorize vowels according to their 3 phonemes.

Estonians show a 4 category pattern.

Prototypes are then selected according to those responses.
Evoked potentials

• 11 normal hearing Estonian subjects

standard [e] measure

same MMN amplitude in Estonian subjects!
Evoked potentials

• 13 normal hearing Finnish subjects

S1  S2  S3  S4  S5  Time
A   A   A   B   A   Deviant
A   A   A   A   A   Control

standard [e]  measure

[e] : F2 1940
[e/ö] : F2 1794
[ö] : F2 1533
[õ] : F2 1311
[o] : F2 851

smaller MMN despite bigger acoustic difference!
Evidence for phonemic representation in the brain?

- Language specific response to prototypes
- What other properties would be required to assume a cortical representation of phonemes?
  - Categorical Perception
  - Normalization for acoustic variation that is irrelevant (e.g. speaker, speech rate, phonetic context, etc..)
  - cross-modal integration (McGurk effect)
1) Adults: Categorical perception

Percentage of “different” responses

Dehaene-Lambertz, Neuroreport, 1997
2) Adults: Dependence on native language

Phonetic categories

/ba/  /da/  /Da/

French

Hindi

Dehaene-Lambertz, Neuroreport, 1997
The influence of phonotactics in productions / loanwords

- **Japanese:**
  - contrastive vowel length
  - simple syllable structure:
    - V, CV, VN, CVN
    - VV, CVV, VVN, CVVN

  Loanword adaptations:
  - Sphinx → [sufinkusu]
  - Christmas → [kurisumasu]

- **French:**
  - no contrastive vowel length
  - complex syllable structure:
    - V, CV, VC, CVC, CCVC, CVCC, CCVCC

  Loanword adaptations: Tookio → [tokjo]

→ insert /u/ after coda consonant, or inside onset cluster (insert /o/ after dental stop)

A perceptual effect? (Polivanov, 1931; Sapir, 1925)
Illusory vowels?

Vowel detection task

Speeded ABX task

Conditions:
cluster: ebuze-ebzo
vowel length: ebuze-ebuuzo

Cluster - Vowel score (% error)

Dupoux, Kakehi, Hirose, Pallier, & Mehler (1999)
Language Specific phonotactics? High density ERPs

$\begin{align*}
\text{S1} & \quad \text{B} \\
\text{S2} & \quad \text{B} \\
\text{S3} & \quad \text{B} \\
\text{S4} & \quad \text{B} \\
\text{S5} & \quad \text{A} \\
\end{align*}$

Deviant

Control

6 female voices

male voice

Japanese

French

[mismatch negativity]

Dehaene-Lambertz, Dupoux & Gout (2000)
SUMMARY
Summary

• Overview of the role of perception experiments to understand the phonological system of L2 learners
  – Laboratory phonology / psycholinguistic and behavioral cognitive psychology

• Discussion of some important methods
  – To study phonetic and phonological knowledge
  – To study lexical access and the form of lexical representations

• Introduction to some questions examined by neuro-imaging methods

• Now: Do you have questions??
Moltes gracies!

www.iub.edu/~psyling

THANK YOU!

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