Phonological « deafnesses »:
Summary of research

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What are phonological ‘deafnesses’?

- *Phonological ‘deafnesses’ = difficulties in perceptual processing of specific non-native speech sounds.*

- Examples:
  - Japanese difficulties with English /r/ vs /l/ (Goto, 1971; Miyawaki et al., 1975)
  - Spanish difficulties with Catalan /e/ vs /ɛ/ (Pallier et al, 1997)

→ *Interpretation*: non-native sounds are ‘assimilated’ to the closest native phoneme category. Deafness arises when two sounds are mapped on the same category (Best, 1994; Flege, 1995; Iverson et al, 2003).

Here, we investigate two new types of deafnesses, *suprasegmental* and *phonotactic*. We explore their existence cross-linguistically, their locus within the speech processing system (with RT and brain imagery techniques), and their robustness in bilinguals.
Background: Suprasegmentals and Phonotactics in borrowings

• Vowel *Degemination* in French
  – Phonology:
    • no contrast between short and long vowel
  – Loanwords:
    • “Tokyo” [to:kjo:]  → [tokjo]
    • “Kyoto” [kjo:to]  → [kjoto]
    → *map long vowels onto short ones*

• Stress deletion in French
  – Phonology:
    • no lexical stress; phrase final stress
  – Loanwords:
    • “Clinton” [klɪntɔn]  → [klintɔn]
    • “Arizona” [arɪzəna]  → [arizoná]
    → *shift the stress to phrase final position*

• Vowel *Epenthesis* in Japanese
  – Phonology:
    • legal syllables: V, CV, VN, CVN
    • illegal syllables: *CVC, *CCV, ...
  – Loanwords:
    • “Sphinx” → [sufiNkusu]
    • “Christmas” → [kurisumasu]
    → *insert the vowel [u] in illegal consonant strings*

➢ *are these effects taking place in perception or production?*
➢ *if in perception, where and when?*
➢ *how and when do they develop in infants?*
➢ *are they phonological or acoustic?*
Stress ‘deafness’ observed

a) Stress discrimination in French and Spanish
   Task: multi-talker ABX (A B and X in different talkers)
   e.g.: \[ \begin{array}{c}
   A \rightarrow B \rightarrow X \\
   vasúma \rightarrow vásuma \rightarrow vásuma \\
   vasúma \rightarrow vasumá \rightarrow vasúma 
   \end{array} \]

b) Phoneme discrimination (with orthogonal variation in stress)
   Task: multi-talker ABX, ignore stress
   e.g.: \[ \begin{array}{c}
   A \rightarrow B \rightarrow X \\
   vasúma \rightarrow fásuma \rightarrow fasúma \\
   vasúma \rightarrow fasumá \rightarrow vasumá 
   \end{array} \]

c) Stress vs phonemes discrimination in French, simpler task
   Task: single talker AX
   e.g.: \[ \begin{array}{c}
   A \rightarrow X \\
   vasúma \rightarrow vásuma 
   \end{array} \]

→ French, not Spanish, have difficulties in discriminating contrastive stress
→ Spanish, not French have difficulties in ignoring stress when performing phoneme discrimination
→ stress ‘deafness’ disappears in an AX task without talker variability at short SOA

A robust method to study stress ‘deafness’

- Task: sequence repetition
- Stimuli:
  - númi vs numí
- Procedure:
  - learning a two way classification:
    - númi=[1]
    - numí=[2]
  - transcribing a sequence
    - númi numí numí=[122]
  - sequences of increasing lengths: from 2 to 6
- Participants:
  - Monolingual French subjects

→ Stress deafness in a short term memory task only arise when the stimuli incorporate enough acoustic variability to discourage an acoustic response strategy

Cross-linguistic stress ‘deafness’

<table>
<thead>
<tr>
<th></th>
<th>Spanish</th>
<th>French</th>
<th>Finnish</th>
<th>Hungarian</th>
<th>Polish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lexical Stress</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Stress Pattern</td>
<td>Variable (last 3 syllables)</td>
<td>Phrase final</td>
<td>Word initial</td>
<td>Word initial</td>
<td>Word penult</td>
</tr>
<tr>
<td>(word level)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stress Pattern</td>
<td>Variable</td>
<td>Utterance final</td>
<td>Utterance final</td>
<td>Utterance final (modulo function words)</td>
<td>Variable (last or penult)</td>
</tr>
<tr>
<td>(utterance level)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- task: sequence repetition
- sequence lengths: 2-6

→ Stress deafness generalizes to languages with initial stress like Finnish or Hungarian
→ Polish, a language with penult stress has only a marginal trend towards stress deafness.
→ interpretation: languages with transparent stress regularities loose the phonological representation of stress; languages with less transparent stress systems tend to keep it.

### Cross-linguistic stress ‘deafness’ (bis)

<table>
<thead>
<tr>
<th>Language</th>
<th>domain of stress</th>
<th>contrastive suprasegmentals</th>
<th>variability in position of stress</th>
<th>lexical exceptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard French</td>
<td>phrase</td>
<td>none</td>
<td>fixed&lt;sup&gt;a&lt;/sup&gt;</td>
<td>no</td>
</tr>
<tr>
<td>Southeastern French</td>
<td>phrase</td>
<td>none</td>
<td>variable&lt;sup&gt;b&lt;/sup&gt;</td>
<td>no</td>
</tr>
<tr>
<td>Finnish</td>
<td>word</td>
<td>vowel length</td>
<td>fixed&lt;sup&gt;c&lt;/sup&gt;</td>
<td>no</td>
</tr>
<tr>
<td>Hungarian</td>
<td>word</td>
<td>vowel length</td>
<td>fixed&lt;sup&gt;c&lt;/sup&gt;</td>
<td>no</td>
</tr>
<tr>
<td>Polish</td>
<td>word</td>
<td>none</td>
<td>variable&lt;sup&gt;d&lt;/sup&gt;</td>
<td>yes (0.1%)</td>
</tr>
<tr>
<td>Spanish</td>
<td>word</td>
<td>stress</td>
<td>variable&lt;sup&gt;e&lt;/sup&gt;</td>
<td>yes (17%)</td>
</tr>
</tbody>
</table>

<sup>a</sup> final,  <sup>b</sup> last non-schwa syllable,  <sup>c</sup> initial,  <sup>d</sup> penultimate in polysyllables,  <sup>e</sup> final in monosyllables,  <sup>f</sup> one of the last three syllables

- **Subjects:** N=12 in each language
- **Task:** sequence repetition
  - Conditions: stress vs phoneme
  - sequence length: 5

→ Three classes of languages:
  - Totally deaf: French, SE French, Finnish, Hungarian
  - Partially deaf: Polish
  - Not Deaf: Spanish
→ **Interpretation:** lexical exceptions make the right predictions
→ **Problem:** incompatible with early acquisition of the French-Spanish contrast
→ **Alternative interpretation:** variability in position of stress (modulo sentence-observable phonological rules, ie, b.)

The persistence of stress deafness

Participants: French late learners of Spanish

<table>
<thead>
<tr>
<th></th>
<th>Beginner</th>
<th>Intermediate</th>
<th>Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of residence in Spanish speaking countries</td>
<td>0.7 year</td>
<td>2 years</td>
<td>4.3 years</td>
</tr>
<tr>
<td>Regularly speaks Spanish in private life</td>
<td>7%</td>
<td>61%</td>
<td>68%</td>
</tr>
<tr>
<td>Regularly speaks Spanish in professional/student life</td>
<td>32%</td>
<td>50%</td>
<td>64%</td>
</tr>
</tbody>
</table>

a) Sequence repetition
- conditions:
  * phoneme: fitu-fiku
  * stress: num’i vs n’umi
- sequences of size 4

b) Speeded lexical decision
conditions:
  * test: « balc’on » vs « b’alcon »
  * control: « blanco » vs « blanto »

→ Stress deafness is very persistent, and still found in relatively proficient late learners of Spanish

Stress « deafness » in simultaneous bilinguals?

Subjects:
- 23 simultaneous bilinguals (from birth)
- 20 control Spanish monolinguals
- 20 control French late learners of Spanish

Tasks:
a) Sequence repetition
   - conditions: stress (num’i - n’umi) vs phoneme (fitu-fiku)
   - sequences of size 2-6
b) Idem with sequences of size 4 only
c) Speeded lexical decision
   - stress word-nonword minimal pairs (bal’on -b’alon )

Measures:
- Deafness index=composite Z-score across the 3 tasks
- Biographic and subjective dominance measures

→ Simultaneous bilinguals are bimodal, one mode is similar to native Spanish, the other to native French (late learners of Spanish)
→ Early childhood, not current use or subjective preference, influences which mode is chosen.

The acquisition of stress ‘deafness’

- **Subjects**
  - Spanish 9 month olds
  - French 9 month olds

- **Experiment 1**
  - switch design
  - High variability stimuli: (d’atu, s’api, k’iba, etc) vs (dat’u, sap’i, kib’a, etc.)

- **Experiment 2**:
  - Low variability stimuli: p’ima vs pim’a

→ At 9 months, French infants have already the stress ‘deafness effect’
→ the acquisition of the distinction between predictable and unpredictable stress cannot be lexically driven

*Language-Specific stress perception by nine-month-old French and Spanish infants.*
Developmental Science, 12:6, 914-919
phonotactic ‘deafness’ observed: perceptual epenthesis

Vowel detection

ABX Task

Conditions:

cluster: ebużo-ebzo
vowel length: ebużo -ebu zo

Cluster - Vowel score (%)

Phonotactic deafness is prelexical

- Speeded lexical decision
  - words:
    - u-set: sokudo
    - nonuset: mikado
  - nonwords created by changing the vowel (u → a or vice versa)
  - cluster items created by removing the vowel
  - Participants:
    - monolingual Japanese subjects

→ the insertion of epenthetic /u/ occurs prior to lexical access

<table>
<thead>
<tr>
<th></th>
<th>u-set</th>
<th>nonu-set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonword</td>
<td>sokado</td>
<td>mikado</td>
</tr>
<tr>
<td>Cluster</td>
<td>sokdo</td>
<td>mikdo</td>
</tr>
<tr>
<td>Word</td>
<td>sokudo</td>
<td>mikado</td>
</tr>
</tbody>
</table>

The time course of phonotactic deafness

**Mismatch detection paradigm**

- **Time:** 600 ms
- S1, S2, S3, S4, S5
- B, B, B, B, A (Deviant)
- A, A, A, A, A (Control)

**Behavioral results**

- Ebuze … Ebizo
- Ebzo … Ebizo
- Ebzo … Ebuzo
- Ebuze … Ebuze
- Ebzo … Ebzo

**High density ERPs results**

- Japanese
- French

- [ebuzo] vs [ebzo] (deviant vs control)

- Same distribution and timing as Mismatch Negativity

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### The brain correlates of phonotactic deafness

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Phonological</th>
<th>Acoustic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>French</td>
<td>ebuoz – ebuoz – ebuoz</td>
<td>ebuoz – ebuoz – ebuuzo</td>
</tr>
</tbody>
</table>

- **Task:** AAX discrimination, single talker.
- **Participants:** French and Japanese monolinguals

→ Phonological processing involves early acoustic processing areas, and areas involved in short term memory.

**p<.005**

- **Supramaginal Gyrus**
- **Heschel’s Gyrus**

Plasticity of phonotactic deafness: Japanese Brazilian immigrants

Populations

**Usage in Japanese/Brazilian**

<table>
<thead>
<tr>
<th>Population</th>
<th>0-5 years</th>
<th>20 years-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jap Monol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>First Generation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second Generation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simultaneous Bil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late Learners</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Br. Monol</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tasks

- **Explicit**: Vowel identification in illegal clusters (ebzo)
- **Implicit**: Sequence recall

→ Early learners (2\textsuperscript{nd} Gen & Simult) drop the phonology of their mother tongue in favor of the dominant language in the environment.

→ Late learners (1st Gen & Late) retain the phonology of their childhood language.

→ Implicit or on-line tasks show a more categorical, monolingual processing profile than explicit or off-line tasks.

The acquisition of phonotactic deafness

- **Experiment 1**
  - switch design
  - High variability stimuli: (abuna, ebudo, iguna, etc) vs (abna, ebdo, igna, etc.)
  - participants: 8-month olds and 14 month olds, Japanese and French infants
- **Experiment 2:**
  - Low variability stimuli: abuna vs abna

→ At 14 months, Japanese infants already have the epentheses effect
→ At 8 months, the acquisition is underway
→ the acquisition of the epentheses effect cannot be lexically driven

Is phonotactic deafness phonological or phonetic?

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Syllabic structure</td>
<td>*CVC&lt;sub&gt;nasal&lt;/sub&gt;</td>
<td>*CVC&lt;sub&gt;stop&lt;/sub&gt;</td>
<td>*CVC&lt;sub&gt;stop&lt;/sub&gt;</td>
</tr>
<tr>
<td>Phonetic structure</td>
<td>i and u devoicing</td>
<td>i and u devoicing</td>
<td>Unstressed vowel deletion</td>
</tr>
<tr>
<td>Epenthesis in the grammar</td>
<td>u or i</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Epenthesis in loanwords</td>
<td>u</td>
<td>i</td>
<td>no</td>
</tr>
</tbody>
</table>

- Task 1: Vowel categorization
  stimuli: - ebizo → eb(i)zo continuum
            - ebuzo → eb(u)zo continuum
            - natural cluster ebzo

- Task 2: Speeded multitalker ABX discrimination
  stimuli: - ebizo, ebuzo, eb(i)zo, eb(u)zo, ebzo

→ No epenthesis in EP, despite same syllabic constraints as BP.
→ In BP and Jap, coarticulation cues influences the epenthetic vowel
→ Same results in vowel cat. & ABX tasks
→ Interpretation: perceptual epenthesis is phonetically driven

In brief

• What we know about phonological ‘deafnesses’
  – it takes place in perception
    • before lexical recognition
    • before input to short term memory buffer
    • after acoustic/auditory analysis
  – it is very robust (if acoustic strategies are prevented)
  – it is driven by the phonological/phonetic properties of the language
  – it strongly resists training through the late acquisition of a second language
  – It is acquired during early childhood (9-14 months)

• What we don’t know
  – how phonological (as opposed to phonetic) are the effects?
  – What are the learning mechanisms involved?
  – what consequences for models of perceptual processing?
  – what consequences for models of loanword adaptations?
See also

• **Language-specific listening** *(other papers by E. Dupoux)*

• **Phonotactic effects on perception**

• **Suprasegmental ‘deafness’**

• **Segmental ‘deafness’**

• **Loanwords**
Thanks

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- Jacquemot C.
- Kakehi, K.
- Leibihan D.
- Limissuri, R.A.
- Mehler, J.
- Nakamura, K.
- Navarete, E.
- Pallier C.
- Parlato, E.
- Peperkamp, S.
- Pons, F.
- Sebastian-Galles, N.
- Skoruppa, C.
- Vendelin, I.