Individual differences in phonological and acoustic memory and L2 vowel perception

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Individual differences in cognitive ability related to speech processing

> a source of inter-learner variability in L2 speech learning and ultimate attainment in L2 pronunciation.

Speech-related cognitive skills
- working memory
- phonological short-term memory
- acoustic memory
- attention control
- inhibition

> Interaction between learning context and cognitive skills

Factors affecting L2 phonological acquisition

Learning conditions:
- L1 background
  (Flage, Botto, & Jang, 1997)
- AOL & length of L2 exposure
  (Flage, Yeni-Komshian, & Liu, 1999)
- Amount of L1/L2 use
  (Guion et al., 2000)

Cognitive abilities:
- Working memory
  (MacKay, Meador & Flege, 2001; Service 1992; Musolins & Lahercigole, 1999; Papagno & Valler, 1995)
- Attention control
  (Guion & Pedersen 2007; Saharihara & Mora 2012; Segalowitz & Frenkel-Fishman 2005)
- Inhibition
  (Darcy, Mora & Daidone 2013; Lev-Ari & Peperkamp 2012)
- Lexical retrieval
  (Segalowitz 1997)
- Vocabulary size
  (Bundgaard-Nielsen, Best & Tyler, 2011)

When controlled, individual differences remain in L2 phonological development
(e.g. Pallier et al. 1997)

Not well known: how these factors relate to L2 phonological development in perception and production

Cognitive abilities:
- Working memory
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- Attention control
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How L2 phonological knowledge develops

Early L1 linguistic experience interferes with L2 phonetic learning in adulthood.

Difficulty in the perception (>production) of L2 sounds can be predicted on the basis of crosslinguistic similarity between L1 and L2 sounds:

Higher perceptual similarity =
  Higher difficulty in perceiving differences
  L2-L1 sound assimilation + likely
  Formation L2 sound category - likely
  Pronunciation less accurate

Based on research (since 1990s) by:
  Flage & colleagues (SLM)
  Best & colleagues (PAM-L2)
  Kuhl & colleagues (NLM-e)

Phonological development in the L1

Exposure to linguistic input in the ambient language sensitizes children to distributional properties creating language-specific phonetic representations (phonetic categories). Children become attuned (neurally committed) to the speech sounds in the ambient language by age 6-12 months.

Phonetic categories in perceptual space

Based on PAM & PAM-L2 (Best, 1995; Best & Tyler, 2007)
L2 speech processing

Learners need to:
- Perceive differences between L1 & L2 sounds. (cross-language speech perception)
- Perceive differences between L2 sounds. (L2 speech perception: - between / within categories)

Differences:
- fine-grained phonetic detail
- phonological / distinctive
- cue weighting

- Sound contrasts need to be encoded in the phonological representation of lexical items (Darcy et al. 2012).

How L1 phonological knowledge develops

> Given the nature of the speech processing mechanisms involved in the encoding of L1/L2 phonological information:

Cognitive Skills ⇔ L2 phonological competence

Develop cognitive tasks should trigger the processes and resources speakers need to resort to when decoding and encoding L2 speech (speech-based)

2 examples:
- Phonological Short-Term Memory Task
- Acoustic Memory Task

Cognitive abilities and L2 vowel perception

Participants are 70 bilingual Spanish/Catalan advanced EFL learners (selected from a larger pool).
- FC AXB Categorial Discrimination Test (Moya-Galé & Mora, 2011)
  - 6 speakers (3 female, 3 male)
  - 120 Natural tokens (bead-bead-bid)
  - 120 Duration-neutralized tokens (same vowel duration for bead-bid within each trial)
  - Different tokens within trial
  - Different speakers within trial
  - Encoding of phonological elements and their serial order and storing them in LTM necessary for language processing.
  - PM stores verbal information
  - holds phonological strings (acoustic information) for a few seconds (around 7 “chunks” or representations)
  - memory is refreshed through sub-vocal rehearsal
  - maintains information in the phonological store
  - registers words in the phonological store

Individuals vary in their language processing capacity

PhD research by: Eva Cerviño (PM)
Elena Safronova (AC)
Serial nonword recognition (SNWR)
Identifying pairs of nonword sequences of increasing length (5-6-7) as Same/Different:
- 5/6/7-item lengths.
- 24 trials: 8 (4S+4D)
  = 12S +12D
- Weighted score X/144
- transposed items
  Except 1st & last
- avoids articulatory effects (cf. Nonword repetition tasks).
- requires phonological encoding (and subvocal rehearsal).
- L1, L2 & L0 ...

Phonological short-term memory (PM)

PM and perception of Natural vs. Manipulated /l/ and /r/
PM made a statistically significant unique contribution (p<.029) explaining: 11.6% Nat stims and 30.6% Man stims

Subject group
High Cat Use
Low Cat Use

PM scores in L1 or L0 (bilinguals) may reliably capture individual differences in PM

What language? L1, L2, L0?
L1? - 5-vowel system (Spanish) > higher PM scores
- Bilingual populations (Cat/Sp) > language dominance effects
L2? - PM scores dependent of L2 proficiency
  - Vocabulary size
  - Level of L2 phonological competence
L0? - Lower PM scores
  - Useful for bilingual populations to avoid dominance effects, but L2-L1 mappings may be different but vowel system size may have an effect

AXB Discrimination

Group differences:
Low PM (N=23)
High PM (N=28)
Nat: p<.043
Man: p<.098

Pearson r PM
DIS Nat n.s. .198
DIS Man n.s. .194

ANOVA within: Nat/Man p<.001
between: Low/High n.s.
Memory capacity for storing acoustic information at a pre-lexical level, i.e. prior to phonological encoding (before intelligibility occurs):

**General auditory processing**

**Acoustic memory (AM)**

**Speech-specific processing of familiar words**

Listeners must process acoustic phonetic features before speech becomes intelligible (can be understood and repeated)

- general auditory processing is involved in speech processing but is not language-specific.
- AM is the storage capacity for the auditory processing of acoustic phonetic features before they are phonologically encoded to make speech intelligible.

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**How can we measure AM?**

**Stimuli should:**

- be non-intelligible
- avoid phonological encoding
- be as acoustically complex as speech

**Rotated Speech (through spectral inversion)**

- non-intelligible (would require specific training).
- as temporally and spectrally complex as speech.
- preserves some speech-like properties (voicing, friction, pitch changes)

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**Sequences of 3 – 4 – 5 – 6 “Rotated Nonwords”:**

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**Phonological short-term memory (PM)**

**Categorial Discrimination Task**

(Oddity Discrimination Format; Flege 1999, 2003)

- 3 male & 3 female NSs of SBE
- 3 contrasts: /b/-/d/-/v/-/s/-/z/; 4 MPs each
- + control contrast /æ/-/i/
- Vowels presented before voiced/unvoiced Cs
- 24 change and 24 no-change trials per contrast

**A’ Score (1=native-like; 0.5=ono sensitivity)**

<table>
<thead>
<tr>
<th>CHANGE TRIALS</th>
<th>NO-CHANGE TRIALS</th>
</tr>
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<tbody>
<tr>
<td>bid bead bid</td>
<td>bead bead bead</td>
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<tr>
<td>bead bead bid</td>
<td>bead bead bead</td>
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<td>bead bid bid</td>
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<td>bid bid bid</td>
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Phonological short-term memory (PM)

You will hear a sequence of THREE WORDS (1 - 2 - 3)
Decide which word contains a different vowel (1 - 2 or 3)
If you hear three words with the same vowel click on SAME

vowel 1  vowel 2  vowel 3

SAME

Sensitivity (A' scores vary as a function of contrast type)

Conclusions

- AM but not PSTM was related to AXB discrimination.
- Similar results in a Categorial DIS task:
  Underdeveloped phonetic categories may prevent learners from using a phonological processing mode?
- Proficiency was not partialled out (vocabulary size can be used as a phonologically-related measure of proficiency).

- Examine the role of PM & AM in cross-language speech perception.
- Examine the role of PM & AM in phonological learning (including lexical representations) through phonetic training

Thank you!
Phonological short-term memory (PM)

Would L0 (Russian) neutralize L1 differences in phonological encoding in Cat/Sp bilingual speakers?

Phonological short-term memory (PM)

- 54 Catalan-Spanish Bilinguals
- ID (cue weighting): natural & duration manipulated MPs
- PM (SNWR): Catalan (L1), English (L2) and Russian (L0).
- PM score (median split) Low vs. High

Stimuli manipulation (Yilmaz et al. 2010):
Tense /i/ was given the duration of lax /i/ (shortened) in every minimal pair produced by every speaker (and lax /i/ → /i/ tense (lengthened))

<table>
<thead>
<tr>
<th>Stimuli</th>
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<tbody>
<tr>
<td>Natural</td>
</tr>
<tr>
<td>voiced</td>
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<tr>
<td></td>
</tr>
<tr>
<td>unvoiced</td>
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</tbody>
</table>
**Phonological short-term memory (PM)**

Cerviño-Povedano, Mora & Aliaga-Garcia 2011

**Acoustic memory (AM)**

(Mora & Cerviño-Povedano 2010)

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- **Phonological short-term memory (PM)**

  Catalan SNWR

  ![Graph showing the relationship between item length and PSTM weighted score (mean percentage)](image)

  - **ItemLength**
    - Subject group: LowCatUse, HighCatUse
    - **Mean Percentage**
      - 80, 75, 70, 65, 60, 55, 50

  **Russian SNWR**

  ![Graph showing the relationship between item length and PSTM weighted score (mean percentage)](image)

  - **ItemLength**
    - Subject group: LowCatUse, HighCatUse
    - **Mean Percentage**
      - 80, 75, 70, 65, 60, 55, 50

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- **Phonological short-term memory (PM)**

  Danish SNWR

  ![Graph showing the relationship between item length and PSTM weighted score (mean percentage)](image)

  - **ItemLength**
    - Use of CAT: Low, High

  ![Graph showing the relationship between sequence length and % correct identification](image)

  - **% correct identification**
    - **(N=54)**
    - Catalan: 5-item 6-item 7-item
      - **Cat:** F(5,2,2)=18.4; p<.001
    - English: 5-item 6-item 7-item
      - **En:** F(5,2,2)=7.58; p=.001
    - Russian: 5-item 6-item 7-item
      - **Rus:** F(5,2,2)=18.4; p<.001

  - Significant main effects of item length (p<.001).
  - Differences were significant between 5- and 6-item lengths.
  - Ns. between 6- and 7-item lengths.

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- **Phonological short-term memory (PM)**

  SNWR rotated Catalan nonwords

  ![Graph showing the relationship between item length and PSTM weighted score (mean percentage)](image)

  - **ItemLength**
    - Use of Catalan: Low, High

  - **Non-sig. Group differences**
    - Sig. effects of item length (all except 2-3)

(Safronova 2011; Safronova & Mora this conference; Safronova & Mora forthcoming)