Individual differences in cognitive ability and L2 speech perception

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Why study individual differences in L2 phonology?

**Acquisition of phonology**

**Pedagogy:**
Pronunciation often is a difficult skill and a *learning challenge* for L2 learners, most learners struggle with pronunciation at most levels of L2 competence.

**Research:**
Learners vary greatly in the amount of foreign accent they exhibit when speaking an L2. We still don’t fully understand the *causes of this inter-learner variation*.

**Social dimension:**
There is an important social dimension to speaking an L2 with a strong foreign accent: integration, self-confidence, …

> help L2 learners with pronunciation
Factors affecting L2 phonological development

Contextual factors:

Age- and experience-related factors

- L1 background
- Age of Onset of L2 learning
- L2 exposure (Length of Residence)
- Frequency/amount of L1/L2 use

Immigrant populations living in L2 community

(Baker et al., 2008; Baker and Trofimovich, 2005; Flege 2009; Flege, Bohn, & Jang, 1997; Flege, Yeni-Komshian, & Liu, 1999; Guion et al., 2000; Moyer 2009; among others)

→ The earlier the start the better for L2 phonology

→ quality and quantity of L2 input received
Factors affecting L2 phonological development

Contextual factors:

- Formal learning context:
  - Classroom instruction
  - Short-term immersion / study abroad

  Student populations in Foreign Language
  (Avello, 2013; Avello, Mora & Pérez-Vidal, 2012; Bongaerts, van Summeren, Planken, & Schils, 1997; Cebrian, 2006; Díaz-Campos, 2004; Fullana, 2006; García-Lecumberri & Gallardo, 2003; Højen 2003; Mora, 2008; Muñoz & Llanes, in press; Piske, 2007; among others)

  → Very limited gains in L2 phonology

- Phonetic training in the lab (esp. high variability)

  Adult learners in L1 & L2 contexts
  (Bradlow et al. 1999; Hazan et al., 2005; Iverson and Evans 2009; Logan et al. 1991; Ylinen et al. 2010; among others)

  → Robust gains in L2 speech perception and production
Factors affecting L2 phonological development

Very large inter-subject variation even in the LAB context where **INPUT** and **EXPOSURE** factors are tightly controlled in the experimental design.


**Individual factors:**

- Motivation
- Personality (extroversion, introversion)
- Musicality (singing and musical ability)
- Sound processing skills (auditory acuity, frequency discrimination)
- Imitation skills (aptitude for oral mimicry)
- Cognitive skills (working memory, attention, inhibition)
- ..... (Bongaerts et al., 1997; Christiner & Reiterer, in press; Hazan & Kim, 2012; Kim & Hazan, 2010; Lengeris & Hazan, 2010; Moyer, 1999; Gottfried, 2007; Slevk and Miyake, 2006; Reiterer et al. 2011; Hu et al. 2013)
Factors affecting L2 phonological development

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- Personality (extroversion, introversion)
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- Imitation skills (aptitude for oral mimicry)
- Cognitive skills (memory, attention, inhibition)
- …..

(Bongaerts et al., 1997; Christiner & Reiterer, in press; Hazan & Kim, 2012; Kim & Hazan, 2010; Lengeris & Hazan, 2010; Moyer, 1999; Gottfried, 2007; Slevk & Miyake, 2006; Reiterer et al. 2011; Hu et al. 2013)
Factors affecting L2 phonological development

Cognitive factors:

- Working memory (WM)
- Phonological short-term memory (PM)
- Acoustic memory (AM)
- Attention Control (AC)
- Inhibition (INH)
- ...

(Cerviño-Povedano & Mora, 2011; Darcy et al. 2011; submitted; Lev-Ari & Peperkamp, 2013; MacKay et al., 2001; Masoura & Gathercole, 1999; Papagno & Vallar, 1995; Safronova & Mora, 2013; Segalowitz 1997; Service 1992;
Factors affecting L2 phonological development

Cognitive factors:
- Working memory (WM)
- Phonological short-term memory (PM)
- Acoustic memory (AM)
- Attention Control (AC)
- Inhibition (INH)
- ...

To what extent do learners’ individual differences in their capacity and use of these skills relate to their L2 phonological development?

(Cerviño-Povedano & Mora, 2011; Darcy et al. 2011; submitted; Lev-Ari & Peperkamp, 2013; MacKay et al., 2001; Masoura & Gathercole, 1999; Papagno & Vallar, 1995; Safronova & Mora, 2013; Segalowitz 1997; Service 1992;)
Cognitive skills and L2 speech perception

Cognitive ability

- Phonological short-term memory (PM)
- Acoustic memory (AM)
- Attention control (AC)
- INHIBITION (INH)

→ L2 phonological acquisition
  - Phonetic training
  - Cross-language speech perception
  - Training cognitive skills
  - L2 phonological development
Cognitive skills and L2 speech perception

Cognitive ability

- Phonological short-term Memory (PM)
- Acoustic Memory (AM)
- Attention Control (AC)
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→ L2 phonological acquisition

- Phonetic training
- Cross-language speech perception
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Cognitive skills and L2 speech perception

Cognitive ability

- Phonological short-term Memory (PM)
- Acoustic Memory (AM)
- Attention Control (AC)
- INHIBITION (INH)

L2 phonological acquisition

- Phonetic training
- Cross-language speech perception
- Training cognitive skills
- L2 phonological development

Speech-based tasks

Categorization tasks:
- Forced choice identification
- AXB / ABX Discrimination
- Oddity discrimination

Stimuli:
- L2 words / nonwords
- L2 English (and L2 Spanish)
Advantages of language- or speech-based tasks

- Measures relate more directly to recruitment of cognitive resources required in language processing
e.g. syntax, semantics, phonology

- Different cognitive skills may be involved in different ways in different domain-specific language functions
e.g. inhibition in language switching vs. inhibition in lexical access and retrieval

→ BUT - less “universal/pure”? - biased? > language knowledge
Phonological short-term memory (PM)

- Responsible for encoding of phonological elements and their serial order and storing them in LTM.
  - necessary for language processing
  - Individuals vary in their PM capacity

(Baddeley and Hitch 1974; Baddeley 1986, 2000, 2003)
Phonological short-term memory (PM)

Responsible for encoding of phonological elements and their serial order and storing them in LTM.

- necessary for language processing
- Individuals vary in their PM capacity

PM stores auditory-verbal information temporarily

- Decaying auditory traces are refreshed through sub-vocal articulatory rehearsal mechanism

- Capacity: few secs. / 7 auditory representations

(Baddeley and Hitch 1974; Baddeley 1986, 2000, 2003)
Phonological short-term memory (PM)

Learners with larger PM capacity may be more efficient in the processing of L2 sounds:

- Speech segmentation.
- Phonological and lexical encoding.
- Cross-language speech perception: L1-L2 sound differences.
- Perception of acoustic differences between contrasting L2 sounds.

Phonological short-term memory (PM)

Serial nonword recognition (SNWR)
Identifying pairs of nonword sequences (in L1) of increasing length as Same/Different

<table>
<thead>
<tr>
<th>Catalan</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>different</td>
<td>[bur]</td>
<td>[gɛtʃ]</td>
<td>[ɔ\text{an}]</td>
<td>[sɔ\text{v}]</td>
<td>[fɛɾ]</td>
<td>[bɪɲ]</td>
</tr>
<tr>
<td></td>
<td>[bur]</td>
<td>[gɛtʃ]</td>
<td>[sɔ\text{v}]</td>
<td>[ɔ\text{an}]</td>
<td>[fɛɾ]</td>
<td>[bɪɲ]</td>
</tr>
<tr>
<td>same</td>
<td>[ɔ\text{ɔs}]</td>
<td>[lɛɾ]</td>
<td>[rin]</td>
<td>[tɛʃ]</td>
<td>[ɔ\text{an}]</td>
<td>[ʁup]</td>
</tr>
<tr>
<td></td>
<td>[ɔ\text{ɔs}]</td>
<td>[lɛɾ]</td>
<td>[rin]</td>
<td>[tɛʃ]</td>
<td>[ɔ\text{an}]</td>
<td>[ʁup]</td>
</tr>
</tbody>
</table>

- CVC nonword sequences are 5, 6, and 7 items in length
- 8 trials (4S+4D) at each sequence length = 24 (12S+12D)
- All vowels in a sequence are different.
- Score % correctly identified sequences (weighted)

(French and O’Brien, 2008; Isaacs & Trofimovich, 2010; O’Brien et al., 2006, 2007)
Phonological short-term memory (PM)

Serial nonword recognition (SNWR)
Identifying pairs of nonword sequences (in L1) of increasing length as Same/Different

> requires phonological encoding (and subvocal rehearsal).
Phonological short-term memory (PM)

SNWR task provides a **language-dependent** measure of PM

Cerviño-Povedano, Mora & Aliaga-Garcia (2011)
<table>
<thead>
<tr>
<th>Language</th>
<th>Catalan</th>
<th>Russian</th>
<th>Danish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phonological short-term memory (PM)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Phonological short-term memory (PM)

PM and AXB discrimination of natural (Nat) and duration-manipulated (Man) /i:/ and /i/:

AXB sheep – ship – ship vs. sheep – sheep – ship

Mora & Cerviño-Povedano (2010)
Phonological short-term memory (PM)

PM and perception of duration-manipulated /fiːt/ and /fɪt/

Forced choice identification of pictures for feet or fit.

Cerviño-Povedano and Mora (2011)
Phonological short-term memory (PM)

PM and perception of vowel contrasts in an oddity discrimination task.

<table>
<thead>
<tr>
<th>CHANGE TRIALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>bid_bead_bead</td>
</tr>
<tr>
<td>bead_bid_bead</td>
</tr>
<tr>
<td>bead_bead_bid</td>
</tr>
</tbody>
</table>

A’ score (1=native-like; 0.5=no sensitivity)

Cerviño-Povedano, in progress
Acoustic memory (AM)

AM is a memory storage for acoustic information listeners use to encode phonological units.

It is involved in the auditory processing of acoustic-phonetic properties of speech sounds before phonological encoding.

- within-category acoustic differences for L2 sounds
- cross-language differences between similar sounds
- L2-specific weighting of phonetic cues (e.g. temporal and spectral information in vowels or voicing in consonants):
  - underlying phonetic properties of speech sounds

Acoustic memory (AM)

How can we measure AM?

Stimuli should:
- not involve phonological encoding
- be non-intelligible
- 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 most speech-like properties (voicing, friction, pitch changes)

(Blesser, 1992; Cowan & Morse 1986; Crowder & Morton 1969; Jacquemot *et al.*, 2003; Scott *et al.* 2000)
Acoustic memory (AM)

[maɲ]

Rotated [maɲ]
Sequences of 3 – 4 – 5 – 6 “Rotated Nonwords”:

Acoustic memory (AM)

(Safronova, 2011; Safronova & Mora, 2012)
Acoustic memory (AM)

AM and AXB discrimination (/ɪ:/ and /i/)
Attention Control (AC)

Phonological attention control:
A person’s ability to shift focus of attention from one attention-directing function of speech (e.g.: duration) to another (e.g. voice quality)

> L2 use is a complex cognitive task that requires the foregrounding and backgrounding of linguistic information.
  > Language as an attention-directing system.
  > Linguistic skill as rapid & flexible control over the attention-directing functions of language.

How can Attention Control be operationalized?
> alternating runs procedure requiring switching between tasks where the dimensions under focus appear predictably.

(Monsell, 2003; Rogers & Monsell, 1995; Segalowitz & Frenkel-Fishman, 2005; Segalowitz, 2010)
Attention Control (AC)

Task-switching paradigm: predictable alternating runs

Number

Letter

odd  Left key  vowel

even  Right key  consonant

Rogers & Monsell (1995)
Attention Control (AC)

Task-switching paradigm: predictable alternating runs

Number

E7

Letter

odd  Left key  vowel

even  Right key  consonant

Rogers & Monsell (1995)
Attention Control (AC)

Task-switching paradigm: predictable alternating runs

Number

A4

Letter

odd  Left key  vowel

even  Right key  consonant

Rogers & Monsell (1995)
Attention Control (AC)

Task-switching paradigm: predictable alternating runs

- **Number**
- **Letter**

<table>
<thead>
<tr>
<th>Odd</th>
<th>Left key</th>
<th>Vowel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Even</td>
<td>Right key</td>
<td>Consonant</td>
</tr>
</tbody>
</table>

Rogers & Monsell (1995)
Task-switching paradigm: predictable alternating runs

Number

Letter

S5

odd Left key vowel

even Right key consonant

Rogers & Monsell (1995)
Attention Control (AC)

Task-switching paradigm: predictable alternating runs

Number

6J

Letter

odd Left key vowel

even Right key consonant

Rogers & Monsell (1995)
Attention Control (AC)

Task-switching paradigm: predictable alternating runs

Number 8U Letter

odd Left key vowel

even Right key consonant

Rogers & Monsell (1995)
Attention Control (AC)

Task-switching paradigm: predictable alternating runs

Odd  Left key  vowel

Even  Right key  consonant

Rogers & Monsell (1995)
Attention Control (AC)

Task-switching paradigm: predictable alternating runs

Number

Letter

2A

odd  Left key  vowel
even  Right key  consonant

Rogers & Monsell (1995)
Task-switching paradigm: predictable alternating runs

Number

E3

Letter

odd  Left key  vowel

even  Right key  consonant

Rogers & Monsell (1995)
Attention Control (AC)

Task-switching paradigm: measures

AC Measures:
- Shift cost = Switch RTs - Repeat RTs
- Error rate = Switch trials + Repeat trials
Attention Control (AC)

A speech-based version of the alternating runs paradigm

Dimension 1: segmental duration (quantity)

(a) short: \(i, e, a, \text{etc.}\)
(b) long: \(i, e, a, \text{etc.}\)

**Duration** is used in English to encode voicing in word-final obstruents and at the same time is secondary to identifying vowel quality distinctions.

Dimension 2: voice quality

(a) male: \(i, e, a, \text{etc.}\)
(b) female: \(i, e, a, \text{etc.}\)

**Pitch** is very important in speech. Besides identifying talkers on the basis of sex and age, pitch changes are used linguistically to convey meaning, as with intonation.

(Safronova 2011; Safronova & Mora 2013)
Attention Control (AC)

A person’s ability to shift focus of attention from one speech-based attention-directing function to another

Time (s) 0.07458 0.6911
Frequency (Hz) 0.0745787854 0.691117031

Time (s) 0.08064 0.8505
Frequency (Hz) 0.0806364247 0.85050821

Foregrounding of duration vs. backgrounding of (partial) closure voicing in word-final obstruents.
Attention Control (AC)

A person’s ability to shift focus of attention from one speech-based attention-directing function to another.

Foregrounding vs. backgrounding temporal and spectral information.

\[ \text{115ms} \quad \text{[biːt]} \]

\[ \text{156ms} \quad \text{[biːt]} \]

\[ \text{355ms} \quad \text{[biːd]} \]
Attention Control (AC)

Task-switching paradigm (speech-based version)

Length

voice

Long Left key Female

Short Right key Male
Attention Control (AC)

Task-switching paradigm (speech-based version)

Length

voice

Long  Left key  Female

Short  Right key  Male
Attention Control (AC)

Task-switching paradigm (speech-based version)

Length

Left key
Female

Long

Left key
Female

Right key
Male

Short
Attention Control (AC)

Task-switching paradigm (speech-based version)

Length

voice

Long
Left key
Female

Short
Right key
Male
Attention Control (AC)

Task-switching paradigm (speech-based version)

Length

Long  Left key  Female

Short  Right key  Male

voice
Attention Control (AC)

Task-switching paradigm (speech-based version)

Length

voice

Long  Left key  Female

Short  Right key  Male
Attention Control (AC)

Task-switching paradigm (speech-based version)

Length

voice

Long  Left key  Female

Short  Right key  Male
Attention Control (AC)

Task-switching paradigm (speech-based version)

<table>
<thead>
<tr>
<th>Length</th>
<th>Voice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long</td>
<td></td>
</tr>
<tr>
<td>Short</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Left key</th>
<th>Right key</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>Male</td>
</tr>
</tbody>
</table>

Long Left key Female

Short Right key Male
Attention Control (AC)

Task-switching paradigm (speech-based version)

Length

Audio

Long  Left key  Female

Short  Right key  Male

Left key
Attention Control (AC)

Task-switching paradigm (speech-based version)

<table>
<thead>
<tr>
<th>Length</th>
<th>Voice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long</td>
<td></td>
</tr>
<tr>
<td>Short</td>
<td></td>
</tr>
<tr>
<td>Left key</td>
<td>Female</td>
</tr>
<tr>
<td>Right key</td>
<td>Male</td>
</tr>
</tbody>
</table>

Keyboard:
- Long: Left key, Female
- Short: Right key, Male
Attention Control (AC)

Results (descriptives $N=83$)

**Error Rate (%) ER**
- **Switch** trials = 8.00
- **Repeat** trials = 5.23

**RTs**
- **Switch** RTs = 1117 ms
- **Repeat** RTs = 923 ms
- **Switch cost** = 193 ms

(Safronova & Mora, 2013)
**Attention Control (AC)**

Results: Error Rate

- **Pearson r**
  - DIS Nat: -.431**
  - DIS Man: -.476**

**ANOVAs**
- within: Nat/Man \( p < .001 \)
- between: Low/High \( p < .001 \)

**Group differences:**
- Low AC ER (\( N = 32 \))
  - Nat: \( p = .002 \)
  - Man: \( p < .001 \)
- High AC ER (\( N = 28 \))

(Safronova & Mora, 2013)
Attention Control (AC)

Pearson $r$  AC SC
DIS Nat  n.s.  -0.039
DIS Man  n.s.  -0.159

ANOVA
within: Nat/Man $p$<.001
between: Low/High n.s.

Group differences:
Low AC SC ($N=30$)
High AC SC ($N=30$)
Nat: $p$=0.572
Man: $p$=0.209

(Safronova & Mora, 2013)
Darcy, Mora & Daidone (2013)

Spain
- Attention Control
- Inhibition

- L2 production
- L2 perception

United States

Spain
- 35 L2 learners of English
- 10 native speakers
  - Universidad de Sevilla (Spain)

United States
- 26 L2 learners of Spanish
- 9 native speakers
  - Indiana University (Bloomington, USA)
Darcy, Mora & Daidone (2013)

Spain
- 35 L2 learners of English
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- Attention Control
- Inhibition
- L2 production
- L2 perception
Perception: speeded categorial ABX task

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>item A</th>
<th>item B</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spanish</td>
<td>saˈreβo</td>
<td>saˈðeβo</td>
<td>Test C</td>
</tr>
<tr>
<td>English</td>
<td>səˈʃi:dən</td>
<td>səˈtʃi:dən</td>
<td>Test C</td>
</tr>
<tr>
<td>Spanish</td>
<td>faˈneða</td>
<td>faˈneɪða</td>
<td>Test V</td>
</tr>
<tr>
<td>English</td>
<td>fəˈni:dɪʃ</td>
<td>fəˈni:dɪʃ</td>
<td>Test V</td>
</tr>
<tr>
<td>Spanish</td>
<td>gaˈtaso</td>
<td>gaˈðaso</td>
<td>Control C</td>
</tr>
<tr>
<td>English</td>
<td>gəˈtæfɪn</td>
<td>gəˈdæfɪn</td>
<td>Control C</td>
</tr>
<tr>
<td>Spanish</td>
<td>luˈpito</td>
<td>luˈpato</td>
<td>Control V</td>
</tr>
<tr>
<td>English</td>
<td>ləˈpiːdɪk</td>
<td>ləˈpædɪk</td>
<td>Control V</td>
</tr>
</tbody>
</table>
Perception results: speeded categorial ABX task

Test

Control

L1: English  Spanish  English  Spanish

Error bars: +/- 1 SE
Attention Control (AC)

Switch-Repeat alternation of stimuli

- Attention switching between acoustic dimensions: **Nasality** vs. **Native language phonetics**

<table>
<thead>
<tr>
<th>Spanish Nasal</th>
<th>English Nasal</th>
</tr>
</thead>
<tbody>
<tr>
<td>'noma</td>
<td>'noʊmeə</td>
</tr>
<tr>
<td>'nole</td>
<td>'noʊleɪ</td>
</tr>
<tr>
<td>'niso</td>
<td>'nɪsoʊ</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spanish Nonnasal</th>
<th>English Nonnasal</th>
</tr>
</thead>
<tbody>
<tr>
<td>'piɣo</td>
<td>'pɪgoʊ</td>
</tr>
<tr>
<td>'dofe</td>
<td>'doʊfeɪ</td>
</tr>
<tr>
<td>'saso</td>
<td>'sæsoʊ</td>
</tr>
</tbody>
</table>

- 2 stimuli sets (**Spanish & Am.English**)
- 2 native **bilinguals** recorded 2 stimuli sets.
Attention Control (AC)

Question ➔ Auditory stimulus ➔ Response

Example: L1-English learner of L2-Spanish

English? 

YES    NO
Attention Control (AC)

Question  →  Auditory stimulus  →  Response

Example: L1-English learner of L2-Spanish

English?

YES  NO
Attention Control (AC)

Question → Auditory stimulus → Response

Example: L1-English learner of L2-Spanish

Nasal?  

YES  

NO
Attention Control (AC)

Question → Auditory stimulus → Response

Example: L1-English learner of L2-Spanish

Nasal?

YES  NO
### Attention Control (AC)

<table>
<thead>
<tr>
<th>Question</th>
<th>Auditory stimulus</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>English?</td>
<td>['doʊfeɪ]</td>
<td>YES</td>
</tr>
<tr>
<td>English?</td>
<td>['noma]</td>
<td>NO</td>
</tr>
<tr>
<td>Nasal?</td>
<td>['sæsoʊ]</td>
<td>NO</td>
</tr>
<tr>
<td>Nasal?</td>
<td>['niso]</td>
<td>YES</td>
</tr>
</tbody>
</table>

**Measures:**

RT on **Switch** vs. **Repeat** (baseline) conditions

Switch cost: **Switch** – **Repeat**, for each participant
Attention Control (AC)

Results:

![Bar graph showing mean RT (correct answers only) for L1: English and Spanish under different conditions. The graph includes error bars (+/- 1 SE). The conditions are SWITCH and REPEAT, with an asterisk indicating a significant difference between the conditions.](image)
Attention Control (AC)

Vocabulary test score used as covariate to partial out proficiency

<table>
<thead>
<tr>
<th>Attention (shift cost)</th>
<th>Perception (ABX)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L2 Sp</td>
<td>n.s.</td>
</tr>
<tr>
<td>L2 En</td>
<td>r= -.488*</td>
</tr>
</tbody>
</table>
Inhibition

Inhibitory control:
A person’s ability to bring to the background stimuli (visual, auditory) or stimuli features (colour, shape) that are irrelevant to the mental process at hand.

Inhibition in language and speech:
- Bilingual language control: e.g. L1/L2
  - Inhibition of the language not in use
- Lexical selection in word retrieval processes
  - inhibition as the suppression of activation: higher inhibition > harder to activate (harder to overcome suppression)
- Cue-weighting in L1/L2 speech processing
  - Focusing attention on a cue inhibits another:
    e.g. V Duration is inhibited when processing V quality
(Costa & Santesteban, 2004; Costa, Santesteban & Ivanova, 2006; Lev-Ari & Peperkamp, 2013; Miyake et al., 2000)
Inhibition

Amount of inhibition is related to proficiency level

- Activation HIGH in L1 > strong inhibition
- Activation LOW in L2 (if proficiency is LOW) > little inhibition

- RTs are slower in Switch than Nonswitch trials.
- L1-to-L2 and L2-to-L1 switching costs are asymmetrical:
  > shifting to L1 requires more time (to overcome inhibition)

(Costa & Santesteban, 2004; Costa, Santesteban & Ivanova, 2006; Calabria et al. 2012)
Inhibition

Amount of inhibition = Level of proficiency

- Activation HIGH in L1 > strong inhibition
- Activation LOW in L2 (if proficiency is LOW) > little inhibition

(Costa & Santesteban, 2004; Costa, Santesteban & Ivanova, 2006; Calabria et al. 2012)
Inhibition and L2 phonological acquisition

> Stronger inhibitory skill might result in better inhibition of the language not in use, and to more efficient phonological processing when switching between speech dimensions or languages.

> Learners with better inhibitory control may be more efficient at inhibiting their L1 phonetics and phonology when speaking their L2

> more accurate, less foreign-accented speech

(Lev-Ari & Peperkamp, 2013; Darcy, Mora & Daidone, 2013; Mora & Darcy, 2013)
Inhibition: inhibitory control task

Memorize

- Vegetables
  - Lettuce
  - Potato
  - Artichoke
  - Onion
  - Spinach
  - Tomato
- Animals
  - Duck
  - Snake
  - Elephant
  - Horse
  - Tiger
  - Cow
- Occupations
  - Plumber
  - Teacher
  - Fireman
  - Carpenter
  - Engineer
  - Nurse

Practice

Type: Vegetable-L___

- Vegetables
  - Lettuce
  - Potato
  - Artichoke
  - Onion
  - Spinach
  - Tomato
- Animals
  - Duck
  - Snake
  - Elephant
  - Horse
  - Tiger
  - Cow
- Occupations
  - Plumber
  - Teacher
  - Fireman
  - Carpenter
  - Engineer
  - Nurse

Inhibited

Increased activation

Recognize

- Vegetables
  - Lettuce
  - Potato
  - Artichoke
  - Onion
  - Spinach
  - Tomato
- Animals
  - Duck
  - Snake
  - Elephant
  - Horse
  - Tiger
  - Cow
- Occupations
  - Plumber
  - Teacher
  - Fireman
  - Carpenter
  - Engineer
  - Nurse

RT on inhibited

RT on control

Inhibition score = (RT to inhibited)/(RT to control)

PLUS additional items never presented before (e.g. secretary)
Inhibition: results

(Proficiency partialled out)

- Inhibition

- ABX accuracy

<table>
<thead>
<tr>
<th>Perception (ABX)</th>
<th>Inhibition (score)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L2 Sp</td>
<td>r = .507*</td>
</tr>
<tr>
<td>L2 En</td>
<td>r = .615*</td>
</tr>
</tbody>
</table>
Cognitive skills and L2 speech perception

Cognitive skills

- Phonological short-term Memory (PM)
- Acoustic Memory (AM)
- Attention Control (AC)
- INHIBITION (INH)

L2 phonological competence

- Explain inter-learner variability
- Not all cognitive skills seem to have the same weight, but:
  - variety of cognitive tasks
  - variety of L2 phonological assessment tasks

- L2-Learner populations may differ in crucial respects. E.g., we recently found a much weaker relationship between Inhibitory control and ABX discrimination with a bilingual population in Barcelona.
### Regression Analyses (N=60)

<table>
<thead>
<tr>
<th>Component</th>
<th>Explained Variance</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phonological short-term Memory (PM)</td>
<td>0.01</td>
<td>.945</td>
</tr>
<tr>
<td>Acoustic Memory (AM)</td>
<td>11.3</td>
<td>.007</td>
</tr>
<tr>
<td>Attention Control (AC ER)</td>
<td>3.5</td>
<td>.123</td>
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<tr>
<td></td>
<td>9.5</td>
<td>.013</td>
</tr>
</tbody>
</table>

**AXB discrimination /iː/-/ɪ/**

- \( R^2 = .286 \) (28.6%); \( p = .001 \) (Nat)
- \( R^2 = .285 \) (28.5%); \( p = .001 \) (Man)
PM, AM, AC & L2 Vowel Perception

Regression Analyses

$R^2= .258$ (25.8%); $p= .002$ (Nat)

$R^2= .236$ (23.6%); $p=.004$ (Man)

% Unique Variance Explained

<table>
<thead>
<tr>
<th>Phonological short-term Memory (PM)</th>
<th>Nat</th>
<th>Man</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.23</td>
<td>0.696</td>
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<tr>
<td>0.55</td>
<td>0.552</td>
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</table>

<table>
<thead>
<tr>
<th>Acoustic Memory (AM)</th>
<th>Nat</th>
<th>Man</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.4</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>14.6</td>
<td>0.003</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Attention Control (AC SC)</th>
<th>Nat</th>
<th>Man</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7</td>
<td>0.510</td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td>0.092</td>
<td></td>
</tr>
</tbody>
</table>

AXB discrimination /iː/-/ɪ/
Next steps

- Improving the speech-based tasks to measure cognitive skills. > current PhD work on phonological memory by Eva Cerviño-Povedano

- Training and pedagogy:
  > What is the role of individual differences in cognitive skills on L2 perception and production gains obtained through phonetic training?
  > Can speech-related cognitive functions be trained efficiently for the benefit of L2 phonological development? How?

- What is the role of individual differences in cognitive skills on cross-language speech perception and the formation of L2 phonetic categories? > current PhD work by Elena Safronova.
Thank you!

- Shiri Lev Ari, Sharon Peperkamp (LSCP, Paris)
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- Eva Cerviño-Povedano (Barcelona)
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- Ron Roosevelt (Sevilla)
- Carmen Muñoz (Barcelona)
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- Jeffrey Holliday (Bloomington)
- Danielle Daidone (Bloomington)
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  - Ajut per a la internacionalització de projectes. Facultat de Filologia, UB.

Comments/questions:

mora@ub.edu
References


References


References


References


References


References


References


Polka, 1991


Phonological short-term memory (PM)

(Mora & Cerviño-Povedano 2010)

- 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 (Ylinen et al. 2010):
Tense /ɪː/ was given the duration of lax /ɪ/ (shortened) in every minimal pair produced by every speaker (and lax /ɪ/ → /ɪː/ tense (lengthened))

<table>
<thead>
<tr>
<th>voiced</th>
<th>Natural</th>
<th>Shortening/Lengthening</th>
<th>Manipulated</th>
</tr>
</thead>
<tbody>
<tr>
<td>voiced</td>
<td>425ms /diːd/</td>
<td>425ms → 240ms</td>
<td>/diːd/ 240ms</td>
</tr>
<tr>
<td></td>
<td>240ms /diːd/</td>
<td>240ms → 425ms</td>
<td>/diːd/ 425ms</td>
</tr>
<tr>
<td>unvoiced</td>
<td>245ms /pʰk/</td>
<td>245ms → 165ms</td>
<td>/pʰk/ 165ms</td>
</tr>
<tr>
<td></td>
<td>165ms /pʰk/</td>
<td>165ms → 245ms</td>
<td>/pʰk/ 245ms</td>
</tr>
</tbody>
</table>
Inhibition: Results

- 1 means 2 RTs are the same
- higher bar = higher inhibition (higher RT in inhibited condition)
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Inhibition

Amount of inhibition = Level of proficiency
- Activation HIGH in L1 > strong inhibition
- Activation LOW in L2 (if proficiency is LOW) > little inhibition

Language Switching Task (picture naming)
Trials:
- switch (L1-L2 / L2-L1) and non-switch (L1-L1 / L2-L2)
- language cued by background colour:

Measure: RTs from stimuli onset to voice-key activation

(Costa & Santesteban, 2004; Costa, Santesteban & Ivanova, 2006; Calabria et al. 2012)
Production results: delayed sentence repetition

**Spanish L2**

/e/ - /ɛi/: amount of tongue movement

<table>
<thead>
<tr>
<th></th>
<th>Amount of tongue movement (difference in Bark)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monophthong</td>
<td><img src="#" alt="Graph" /></td>
</tr>
<tr>
<td>Diphthong</td>
<td><img src="#" alt="Graph" /></td>
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</table>

/r/ - /ð/  Average score (max. 8)

<table>
<thead>
<tr>
<th></th>
<th>Mean score</th>
<th>SD</th>
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</thead>
<tbody>
<tr>
<td>L2 learners</td>
<td>4.27</td>
<td>2.20</td>
</tr>
<tr>
<td>n = 26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Native speakers (Spanish)</td>
<td>7.89</td>
<td>0.3</td>
</tr>
<tr>
<td>n = 9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**English L2**

/i:/ - /I/: spectral differences (Bark)

<table>
<thead>
<tr>
<th></th>
<th>B2 - B1</th>
</tr>
</thead>
<tbody>
<tr>
<td>/i:/</td>
<td><img src="#" alt="Graph" /></td>
</tr>
<tr>
<td>/I/</td>
<td><img src="#" alt="Graph" /></td>
</tr>
</tbody>
</table>

/f/ - /f/: Average score (max. 8)

<table>
<thead>
<tr>
<th></th>
<th>Mean score</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>L2 learners</td>
<td>6.89</td>
<td>1.32</td>
</tr>
<tr>
<td>n = 35</td>
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<td>Native speakers (English)</td>
<td>8</td>
<td>0</td>
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<tr>
<td>n = 10</td>
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<td></td>
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</tbody>
</table>
Phonological short-term memory (PM)

Danish
Phonological short-term memory (PM)

Danish
Phonological short-term memory (PM)

Danish
Phonological short-term memory (PM)