The Role Of Phonological Short-term Memory In Spanish L2 Phonology: Exploring Vowel Quality And Duration Among English-speaking Learners

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Special thanks to Lori Lye for her help with data coding!
BACKGROUND: PSTM
Phonological short-term memory (PTSM)

■ Corresponds to the phonological loop of working memory (Baddeley & Hitch, 1974)
  - Short-term phonological store → 2 second decay
  - Articulatory rehearsal, where sub-vocal rehearsal occurs

■ Thought to facilitate the long-term learning of the sound structures of new words and vocabulary acquisition
PSTM and L2 abilities

- **Documented correlations between PSTM and...**
  - *Vocabulary knowledge*  
  - *Knowledge of collocations*  
    (Skrzypek & Singelton, 2013)
  - *Listening comprehension*  
    (Tsuchihira, 2007; Kormos & Safar, 2008)
  - *L2 sound perception*  
    (Cerviño-Povedano & Mora, 2011, 2015; Mackay, Meador & Flege, 2001)
  - *L2 pronunciation*  
    (Kondo, 2012; Nagle, 2013; Sleve & Miyake, 2006; Xiaochen et al., 2013)
BACKGROUND: L2 Vowels
English and Spanish vowels differ significantly (Bradlow, 1995; Delattre, 1965; Ladefoged, 2006; Menke, 2017; Stockwell & Bowen, 1965)

- English has more phonemes (9-14) than Spanish (5)
- Vowels differently located in the acoustic space
- Unstressed vowel centralization in English
Spanish L2 vowels

- English-speaking L2 learners of Spanish...
  - Frequently produce Spanish vowels with differing acoustic properties from native speakers of Spanish
    - /u/ is often fronted at lower levels
    - /e/ demonstrates large degrees of variation
    - etc.
  - Often centralize unstressed vowels

- These differences persist even at advanced levels
  - Although performance generally improves as proficiency increases

(Cobb & Simonet, 2015; Díaz & Simonet, 2015; Menke & Face, 2010; Simões, 1996; Menke, 2015)
CURRENT STUDY
Research questions

■ Do second language Spanish learners with differing PSTM abilities produce the five Spanish monophthongs with differing acoustic properties?
  - High PSTM learners will demonstrate acoustic properties that more closely approximate those of natives
  - High PSTM learners will centralize their unstressed vowels less than those with low PSTM
  - High PSTM learners will produce shorter vowels than those with high PSTM

■ If so, does the effect of PSTM change across levels?
  - Differences according to PSTM will be larger in the 4000-level than the graduate-level
Tasks
[Part of a larger corpus of tasks designed to elicit free response speech and examining cognitive individual differences]

- DELE grammar test
  - 20-item grammar cloze test
    (Embajada de España, Washington, DC; cf. Duffield & White [1999])

- Lextale-ESP Spanish Vocabulary task
  (Izura, Cuetos & Brysbaert, 2014)

- Serial non-word recognition task

- Oral response task
Measure of PSTM

- Serial non-word recognition task [L3 (Russian)]
- 24 pairs of sequences containing between 5-7 Russian CVC words and non-words
  - *Eight each of 5, 6 and 7 non-words*
    - Identical (i.e. A,B,C,D,E; a,b,c,d,e)
    - Different (i.e. A,B,C,D,E; a,c,b,d,e)
    - Recorded by female speaker in a carrier phrase

- Response: same or different?
  - *1000ms for response*

- Presented in OpenSesame
  (Mathôt, Schreij & Theeuwes, 2012)

- Practice block of 4 sequences preceding the test phase
Oral response task

- Participants presented with prompts for an oral response (via PowerPoint)
  - 10 prompts, 10-15 minutes total
- Topics designed to promote a range of discourse types (hypothetical, narrative, description)
- Responses recorded with a TASCAM DR-40 4-Track portable digital recorder with a Shure WH20XLR dynamic headset microphone

“Cuéntame tus planes para este fin de semana.”
## Participants

<table>
<thead>
<tr>
<th>Level</th>
<th>PSTM (/ 144)</th>
<th>DELE (/ 20)</th>
<th>Vocab. (-30 - 60)</th>
<th>Sex</th>
<th>Study Abroad</th>
</tr>
</thead>
<tbody>
<tr>
<td>4000-level</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low PSTM (N = 5)</td>
<td>65</td>
<td>10.6</td>
<td>13</td>
<td>M = 3 F = 2</td>
<td>Yes = 2 No = 3</td>
</tr>
<tr>
<td>High PSTM (N = 5)</td>
<td>116.4</td>
<td>11.2</td>
<td>20.4</td>
<td>M = 1 F = 4</td>
<td>Yes = 2 No = 3</td>
</tr>
<tr>
<td>Graduate-level</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low PSTM (N = 5)</td>
<td>51.4</td>
<td>15</td>
<td>44.2</td>
<td>M = 2 F = 3</td>
<td>Yes = 5</td>
</tr>
<tr>
<td>High PSTM (N = 5)</td>
<td>120.2</td>
<td>14</td>
<td>28.6</td>
<td>F = 5</td>
<td>Yes = 5</td>
</tr>
<tr>
<td>Native</td>
<td>N=2</td>
<td>74</td>
<td>18</td>
<td>F = 5</td>
<td>Spain = 2 Mexico = 1 Puerto Rico = 1 Colombia = 1</td>
</tr>
</tbody>
</table>
Analysis (1)

- Minutes 2-7 excerpted for all participants
- All monophthong vowels marked in Praat
Analysis (2)

- Praat scripts used to extract:
  - *Vowel duration (in ms)*
  - *F1 and F2 vowels (at midpoint)*

- Data normalized using the Neary1 formula in NORM Suite (Thomas & Tyler, 2007); Neary values then scaled to produce normalized formant values

<table>
<thead>
<tr>
<th></th>
<th>4000-level</th>
<th>Graduate-level</th>
<th>Native speakers</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exclusions</td>
<td>177</td>
<td>197</td>
<td>125</td>
<td>499</td>
</tr>
<tr>
<td>Final tokens</td>
<td>3774</td>
<td>5721</td>
<td>2694</td>
<td>12,189</td>
</tr>
</tbody>
</table>
RESULTS: Vowel Quality
Native

4000, low PSTM

4000, high PSTM

Grad, low PSTM

Grad, high PSTM
- Only natives have a /u/ that is posterior to /o/
- 4000-level learners show the most /u/ fronting
- All participants (incl. natives) show tendency to centralize
  - 4000-level learners centralize the most in unstressed syllables, particularly /u/ and /a/
Differences between low PSTM and high PSTM learners:

- **4000-learners:**
  - Low PSTM learners have a more fronted /u/ and /o/
  - Low PTSM learners have a higher, higher /a/ and /i/

- **Graduate-learners:**
  - Significant F1 differences for /i/, /a/, /o/, /u/; Significant F2 differences for all 5 vowels
  - High PSTM grad learners only group with /u/ posterior to /o/
Unstressed vowels in 4000-level and grad PSTM groups

- 4000-learners:
  - More centralization in unstressed syllables for low PSTM
  - /a/ is significantly raised; Significant F2 differences for /e/, /i/, /o/ and /u/

- Graduate-learners:
  - More fronting of /u/ in unstressed syllables for low PSTM

![Graphs showing F1 and F2 frequencies for unstressed syllables across different PSTM groups.](image)
RESULTS: Vowel Duration
- 4000-level learners produce all five vowels with longer durations than both other groups
- Graduate-level learners produce /a/, /e/, /i/ and /o/ with longer durations than NSs

<table>
<thead>
<tr>
<th>Level</th>
<th>/a/</th>
<th>/e/</th>
<th>/i/</th>
<th>/o/</th>
<th>/u/</th>
</tr>
</thead>
<tbody>
<tr>
<td>4000-level</td>
<td>134.1</td>
<td>129.8</td>
<td>160.8</td>
<td>139.9</td>
<td>102.0</td>
</tr>
<tr>
<td>Graduate-level</td>
<td>112.1</td>
<td>105.0</td>
<td>132.0</td>
<td>102.0</td>
<td>83.0</td>
</tr>
<tr>
<td>Native</td>
<td>93.9</td>
<td>83.9</td>
<td>99.0</td>
<td>86.3</td>
<td>75.4</td>
</tr>
</tbody>
</table>
Differences between low PSTM and high PSTM

- 4000-level: high PSTM learners produce all vowels with longer durations than low PSTM learners
- Graduate-level: high PSTM learners produce /e/, /i/ and /o/ with longer durations than low PSTM learners;

<table>
<thead>
<tr>
<th>Level</th>
<th>/a/</th>
<th>/e/</th>
<th>/i/</th>
<th>/o/</th>
<th>/u/</th>
</tr>
</thead>
<tbody>
<tr>
<td>4000-low PSTM</td>
<td>129.8</td>
<td>121.7</td>
<td>147.9</td>
<td>123.7</td>
<td>86.3</td>
</tr>
<tr>
<td>4000-high PSTM</td>
<td>140.4</td>
<td>138.8</td>
<td>173.88</td>
<td>160.6</td>
<td>118.8</td>
</tr>
<tr>
<td>Graduate-low PSTM</td>
<td>114.4</td>
<td>98.0</td>
<td>126.0</td>
<td>97.0</td>
<td>83.1</td>
</tr>
<tr>
<td>Graduate-high PSTM</td>
<td>109.3</td>
<td>114.0</td>
<td>139.7</td>
<td>108.0</td>
<td>83.7</td>
</tr>
<tr>
<td>Natives</td>
<td>93.9</td>
<td>83.9</td>
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DISCUSSION
Research questions REVISITED

- Do second language Spanish learners with differing PSTM abilities produce vowels with differing acoustic properties?
  - High PSTM learners will demonstrate acoustic properties that more closely approximate those of natives
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- If so, does the effect of PSTM change across levels?
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Comparison with previous literature

PSTM

- Effect of PSTM in both advanced levels for vowel quality, centralization and duration
- Differs from previous literature on advanced learners (Sleve & Miyake, 2006; Xiaochen et al., 2013):
  - Task type: reading v. free response
  - Analysis: global pronunciation v. specific class of sounds

L2 vowels

- Similarities
  - Learners produce different qualities
  - Often centralize unstressed vowels
- Differences
  - /u/ in our study is much more fronted than in Menke & Face, 2010
  - BUT oral speech v. reading task
Future Work

- Control for rate of speech
- Further examine relationship with stress
- Examine relationship between duration and vowel quality
- Investigate outliers
Thank you.
Selected References


Tsuchihira, T. (2007). L2 working memory capacity and L2 listening test scores of Japanese junior college students. *Journal of Bunkyo Gakuin University, Department of Foreign Languages and Bunkyo Gakuin College*, 7, 159-175.