When prosody matters!
Emerging word segmentation abilities in European Portuguese learning infants

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Introduction

The word segmentation problem: when and how infants begin to segment word-like forms from the continuous speech stream?

- Early word segmentation plays a crucial role in language acquisition (i.e., word learning, syntax – Newman et al., 2006; Singh et al., 2012)
Introduction

- Segmentation abilities in typically developing infants have been shown to vary across languages (e.g., Jusczyk & Aslin, 1995; Jusczyk et al., 1999; Seidl & Johnson, 2006; Hohle & Weissenborn, 2003, 2005; Bosch et al, 2013; Nazi et al., 2006; Mersad at al., 2010; Nazi et al., 2014).

<table>
<thead>
<tr>
<th>Language</th>
<th>Monosyllabic</th>
<th>Trochaic</th>
<th>Iambic</th>
</tr>
</thead>
<tbody>
<tr>
<td>English</td>
<td>7.5m</td>
<td>7.5m</td>
<td>10.5m</td>
</tr>
<tr>
<td>German</td>
<td>7-9m</td>
<td>9m</td>
<td>11m+</td>
</tr>
<tr>
<td>Spanish/Catalan</td>
<td>6m</td>
<td>-</td>
<td>16m?/8m?</td>
</tr>
<tr>
<td>French</td>
<td>7.5m?</td>
<td>-</td>
<td>16m?/8m?</td>
</tr>
</tbody>
</table>
Introduction

- **Rhythmic properties** of a language (i.e., stress based, syllable based) may be utilised to begin segmenting continuous speech – what the infant relies on (Nazzi et al. 2006)

- Word position may be crucial also due to prosody: Words at **utterance edges/boundaries** easier to segment than those in the middle (Seidl & Johnson, 2006; Johnson et al., 2014)
  - Edge provides particularly **salient cues** e.g. duration and pitch cues

<table>
<thead>
<tr>
<th>Language</th>
<th>Rhythm</th>
<th>Unit</th>
<th>Edge</th>
</tr>
</thead>
<tbody>
<tr>
<td>English</td>
<td>Stress-timed</td>
<td>Word</td>
<td>earlier</td>
</tr>
<tr>
<td>German</td>
<td>Stress-timed</td>
<td>Word</td>
<td></td>
</tr>
<tr>
<td>Spanish</td>
<td>Syllable-timed</td>
<td>Syllable</td>
<td></td>
</tr>
</tbody>
</table>
Present study

- First attempt to study emerging segmentation abilities in European Portuguese (EP) learning infants

- **EP rhythm** displays both stress and syllable timing properties, unlike English or Spanish (Frota & Vigário 2001)

- Also, unlike other languages, EP provides strong cues to high prosodic phrase boundaries and word boundaries, but not to lower phrase boundaries (Vigário, 2003; Frota 2014)
Aims

- Identify at what point in development segmentation abilities emerge

- Investigate whether **prosody** constrains early word segmentation abilities in EP in comparison with other languages
  - Monosyllabic segmentation earlier/later
  - Effect of **prosodic salience** (prosodic boundaries)
Two studies

EP learning infants’ ability to segment *monosyllabic* word forms

**STUDY 1**
5-6 months and 8-9 months

**STUDY 2**
12 months
Method – Study 1
Participants

- **5-6 months:**
  - 20 infants from monolingual homes in the Lisbon area
    (11 boys, mean age 6m 3d, range 4m 19d – 7m 11d)
  - 5 infants excluded due to fussiness (1), risk of autism (1), not needed (3)

- **8-9 months:**
  - 20 infants from monolingual homes in the Lisbon area
    (12 boys, mean age 9m 2d, range 7m 27d – 10m 8d)
  - 0 infants excluded
Method – Study 1

Materials

- 4 monosyllabic pseudo words (CVC/CVG)
  - Ful, Queu, Pis, Sau
- 2 passages constructed for each word, one for middle and one for end sentences

A Marta pôs o seu Ful na mesa. Fizemos festas ao Queu vermelho. Nunca comi Pis com morangos. O Tó desenhou um Pis bonito. Conheço Pis doce do Algarve. Eles disseram Pis muitas vezes.

Internal to the Intonational Phrase (IP)

Prosodically prominent

Final Intonational Phrase edge (=sentence)

Os vizinhos brincam com o teu Queu. Estão sempre a falar-nos do Pis. Elas viajavam muito de Pis. Os anões adoram bolachas e Pis. Quero agradecer tudo ao Pis. A Dora anda no seu grande Pis.
Method – Study 1

Internal to the Intonational Phrase (IP)

Final Intonational Phrase edge (=sentence)

Less Prominent

Prosodically Prominent
Method – Study 1

<table>
<thead>
<tr>
<th></th>
<th>Medial</th>
<th></th>
<th>End</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Sentence Length (ms)</td>
<td>2000.63</td>
<td>143.36</td>
<td>1952.88</td>
<td>154.91</td>
</tr>
<tr>
<td>Syllable Duration Before Boundary (ms)</td>
<td>308.79</td>
<td>52.49</td>
<td>494.50</td>
<td>53.60</td>
</tr>
<tr>
<td>Syllable Duration After Boundary (ms)</td>
<td>203.46</td>
<td>67.98</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pitch Range (hz)</td>
<td>-24.52</td>
<td>32.32</td>
<td>-59.58</td>
<td>21.83</td>
</tr>
<tr>
<td>Pitch Reset (HZ)</td>
<td>-17.75</td>
<td>39.04</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tonal Event</td>
<td>-</td>
<td></td>
<td>L%</td>
<td>-</td>
</tr>
</tbody>
</table>
Method – Study 1

<table>
<thead>
<tr>
<th></th>
<th>Medial: PhP</th>
<th></th>
<th>Medial: PW</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td></td>
</tr>
<tr>
<td>Sentence Length (ms)</td>
<td>2022.69</td>
<td>94.20</td>
<td>1974.55</td>
<td>187.73</td>
<td>.81, $p = .43$</td>
</tr>
<tr>
<td>Syllable Duration Before Boundary (ms)</td>
<td>326.77</td>
<td>46.50</td>
<td>287.55</td>
<td>53.16</td>
<td>1.93, $p = .07$</td>
</tr>
<tr>
<td>Syllable Duration After Boundary (ms)</td>
<td>162.62</td>
<td>35.15</td>
<td>251.73</td>
<td>66.45</td>
<td>4.2, $p &lt; .001$</td>
</tr>
<tr>
<td>Pitch Range (hz)</td>
<td>35.95</td>
<td>16.83</td>
<td>36.99</td>
<td>17.87</td>
<td>.15, $p = .89$</td>
</tr>
<tr>
<td>Tonal Event</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Procedure: modified version of the Visual Habituation Paradigm (Stager & Werker, 1997; Altvater-Mackensen & Mani, 2013)
## Method Study 1

### Familiarisation
- Alternating trials
- 25 secs accumulated listening time to each

<table>
<thead>
<tr>
<th>Passage 1 – End</th>
<th>Block 1</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Randomised order</td>
<td>Block 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Block 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Block 3</td>
</tr>
<tr>
<td>Word 1 – familiar end</td>
<td>Word 2 – familiar mid</td>
<td>Word 3 – novel</td>
</tr>
</tbody>
</table>

### Test

- Randomised order

<table>
<thead>
<tr>
<th>Passage 2 – mid</th>
<th>Block 1</th>
<th>Block 2</th>
<th>Block 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Word 1 – familiar end</td>
<td>Word 1 – familiar end</td>
<td>Word 1 – familiar end</td>
</tr>
<tr>
<td></td>
<td>Word 2 – familiar mid</td>
<td>Word 2 – familiar mid</td>
<td>Word 2 – familiar mid</td>
</tr>
</tbody>
</table>

Trials continue until infant looks away for more than 2 consecutive seconds, or the sound file ends.

Segmentation demonstrated by longer looking times to familiar word forms compared with novel.
Results Study 1

Internal collapses lower prosodic boundary with just a word boundary

5-6 months:
- Significant effect of item status ($F(2,38) = 13.24, p < .001, \eta^2 = .41$).
  - end and middle ($t(19) = 3.38, p < .01$)
  - end and distracter ($t(19) = 4.72, p < .001$)
  - middle and distracter ($t(19) = .91, p = .37$).

8-9 months:
- Significant effect of item status ($F(2,38) = 16.72, p < .001, \eta^2 = .47$).
  - end and middle ($t(19) = 3.44, p < .01$)
  - end and distracter ($t(19) = 6.71, p < .001$)
  - middle and distracter ($t(19) = 2.12, p < .05$).
Method – Study 2
Participiants

- **12 months (medial IP):**
  - 20 infants from monolingual homes in the Lisbon area
    (10 boys, mean age 12m 2d, range 10m 24d – 13m 19d)
  - 2 infants excluded due to fussiness

- **12 months (medial PW):**
  - 20 infants from monolingual homes in the Lisbon area
    (11 Boys, mean age 12m 10d, range 10m 15d– 14m 22d)
  - 3 infants excluded, 2 due to fussiness, 1 experimenter error
Method Study 2
Materials

- Same 4 monosyllabic pseudo words
  - Ful, Queu, Pis, Sau

- Procedure similar as for younger age groups
  - Only familiarised with words in middle of sentences

As rãs gostam de ____, em vez de musgo fresco.
Comprado o ____, voltamos ao parque.
Desde que viu o ____, não quis brincar mais.
Oferecemos-te ____, mas ficaste triste.
Quanto à luz ____, nunca foi testada.
Vocês prendem o ____, porém ele fugiu.
Method Study 2

Materials

- Same 4 monosyllabic pseudo words
  - Ful, Queu, Pis, Sau

Non-prominent internal position, with absence of any phrase boundary

- Procedure similar as for younger age groups
  - Only familiarised with words in middle of sentences

A caixa contém **ful** vermelho na tampa.
Aquele grande **ful** branco é da Quica.
Comeram muito **ful** doce na praia.
Hoje vi um **ful** castanho mas duro.
O amigo do **ful** português fugiu.
O outro **ful** branco foi de mercedes.
Method – Study 2

Sentence internal Intonational Phrase edge

Non-prominent internal position, no phrase boundary

Prosodically Prominent

NOT Prominent
## Method – Study 2

<table>
<thead>
<tr>
<th></th>
<th>IP Boundary</th>
<th></th>
<th>PW Boundary</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Sentence Length (ms)</td>
<td>2740</td>
<td>220</td>
<td>2320</td>
<td>220</td>
</tr>
<tr>
<td>Syllable Duration Before Boundary (ms)</td>
<td>540</td>
<td>40</td>
<td>290</td>
<td>30</td>
</tr>
<tr>
<td>Syllable Duration After Boundary (ms)</td>
<td>230</td>
<td>50</td>
<td>260</td>
<td>60</td>
</tr>
<tr>
<td>Pitch Range (hz)</td>
<td>85.92</td>
<td>37.43</td>
<td>-29.59</td>
<td>14.06</td>
</tr>
<tr>
<td>Pitch Reset (HZ)</td>
<td>-93.45</td>
<td>34.06</td>
<td>-30.58</td>
<td>21.55</td>
</tr>
<tr>
<td>Tonal Event</td>
<td>H%</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Results Study 2

- Significant effect of item status - $F(1,18) = 23.6$, $p < .001$, $\eta^2 = .57$

At internal IP edge

Similar behaviour, segmentation wise, to 5-6 month olds at final IP boundaries (=sentence edge)
Results Study 2

- Significant effect of item status - $F(1,18) = 23.6$, $p < .001$, $\eta^2 = .57$

- No significant effect of item status - $F(1,18) = 1.776$, $p > .1$, $\eta^2 = .090$
Conclusions

- EP learning infants at 5-6 months are able to segment continuous speech only when the word is located at the high prosodic edge (IP boundary, the end of the sentence)
  - In line with recent findings for English learning infants, but against those for Spanish/Catalan infants showing segmentation at 6 months regardless of prosody

- At 8-9 months, EP infants start to segment words in the middle of sentences (lower boundaries), but still demonstrate an advantage for words at the end of sentences
Conclusions

- Portuguese 12-month-old infants are able to segment words in sentence medial position, when target word precedes a **IP boundary** (despite the absence of a pause).
- This shows a sensitivity to prosody in early segmentation, beyond the edge vs. internal position.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final IP edge only</td>
<td>5-6</td>
<td></td>
</tr>
<tr>
<td>Internal lower edges start</td>
<td>8-9</td>
<td></td>
</tr>
<tr>
<td>Internal IP edge</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Not plain internal</td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>
Prosody constrains the emergence and development of early segmentation in EP, in the first year
Thanks to all the infants, families and nurseries that have taken part in these studies.

Obrigada!

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EBELa: EXCL/MHC-LIN/0688/2012
SFRH/BD/80991/2011