Emerging word segmentation skills in atypical development

Sónia Frota, Jovana Pejović, Cátia Severino & Marina Vigário

Lisbon Baby Lab, Center of Linguistics, University of Lisbon, Portugal
sfrota@campus.ul.pt

http://labfon.letras.ulisboa.pt/babylab/
The word segmentation problem: when and how infants begin to segment word-like forms from the continuous speech stream?

It is difficult to find a word in this utterance

eddificilencontraruma palavranesta frase
Typically developing (TD) infants

- Early word segmentation plays a crucial role in language acquisition (i.e., word learning – Newman et al., 2006; Singh et al., 2012; Kidd et al., 2018; Hoareau et al., 2019)

- Segmentation abilities in TD 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; Nazzi et al., 2006; Nazzi et al., 2014; Nishibayashi et al., 2015; Berdasco-Muñoz et al., 2018)

- Segmentation abilities are modulated by prosodic structure: Words at prosodic edges, namely utterance-final position, are segmented earlier than in utterance-medial position (e.g., Johnson et al., 2014; Butler & Frota, 2018)
Atypical development I

- Only a few studies on segmentation abilities in atypical development: Development of this ability is seriously delayed, but the learning path is similar to TD (Nazzy, Paterson & Karmiloff-Smith, 2003; Mason-Apps et al., 2011; Mason-Apps et al., 2018).

<table>
<thead>
<tr>
<th>Clinical Group</th>
<th>Language</th>
<th>Bisyllabic</th>
<th>Age/CDI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Williams Syndrome (19)</td>
<td>English</td>
<td>Trochaic (7.5m)</td>
<td>Failed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Iambic (10.5m)</td>
<td>No/No</td>
</tr>
<tr>
<td>Down Syndrome (9)</td>
<td>English</td>
<td>33 m/19 m</td>
<td>Failed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-/No</td>
</tr>
<tr>
<td>Down Syndrome (11)</td>
<td>English</td>
<td>18-20 m/- - - -</td>
<td>Failed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No later outcomes</td>
</tr>
</tbody>
</table>
Atypical development II

- Two studies on segmentation abilities in infants at risk for language impairments – preterm infants: Mixed findings (Bosch, 2011; Berdasco-Muñoz et al., 2018)

<table>
<thead>
<tr>
<th>Group</th>
<th>Language</th>
<th>Succeeded</th>
<th>Failed</th>
<th>Full-term</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-month olds (maturational)</td>
<td>Spanish</td>
<td>–</td>
<td>CVC, CCVC</td>
<td>Do it</td>
</tr>
<tr>
<td></td>
<td>Catalan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-month-old (post-natal)</td>
<td>French</td>
<td>CV</td>
<td>–</td>
<td>Do it</td>
</tr>
</tbody>
</table>

sfrota@campus.ul.pt
Early segmentation abilities in European Portuguese (EP)-learning infants with Down Syndrome (DS) and at-risk for language impairment (AR)

- Premature birth and familial risk for autism or language disorder

Goals

- Examine whether prosody facilitated word segmentation, as previously shown for TD infants (Butler & Frota, 2018)
  - Early segmentation for prosodic-edge only (earliest evidence for segmentation in the literature)
  - Segmentation at utterance-medial position still developing by 10 months
- As lexical acquisition seems to be delayed in DS and AR (Sansavini et al., 2011), we further asked whether prosody modulated the relation between segmentation abilities and lexical knowledge
If similar mechanisms and/or trajectories guide word segmentation, a similar pattern of results is expected, albeit possibly delayed.
Method

Participants

- **DS**: 25 infants and toddlers (12 girls, mean age 16 months and 12 days, range 7 to 23 months)
- **AR**: 21 infants and toddlers (10 girls, mean age 15 months and 17 days, range 6 to 26 months)
  - preterm birth < 37 weeks (9), familial risk for autism or language disorder (9), and other factors like low Apgar score and reanimation at birth (3)
- Monolingual homes; Normal hearing; Normal or corrected-to-normal vision; No history of seizures/other medical or neurological conditions

sfrota@campus.ul.pt
Stimuli

- 4 monosyllabic pseudo words (CVC/CVG)
  - Ful, Queu, Pis, Sau
- 2 passages constructed for each word, one for **medial** and one for **edge** prosodic conditions; 4 word-lists from different spoken exemplars

Method

**Stimuli**

- 4 monosyllabic pseudo words (CVC/CVG)
  - Ful, Queu, Pis, Sau
- 2 passages constructed for each word, one for **medial** and one for **edge** prosodic conditions; 4 word-lists from different spoken exemplars

Less Prominent

Utterance-medial position

Prosodically prominent

Utterance-edge-final position

A Marta põs o seu **ful** na mesa. Fizemos festas ao **ful** vermelho.

Os vizinhos brincam com o teu **ful**. Estão sempre a falar-nos do **ful**.

http://labfon.letras.ulisboa.pt/babylab/infant_word_segmentation/word_segmentation_supporting_materials.htm

sfrota@campus.ul.pt
### Method

**Stimuli**

<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>Tonal Event</td>
<td>-</td>
<td>L%</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Butler & Frota, 2018

sfrota@campus.ul.pt
### Procedure

Modified version of the visual habituation paradigm (Altvater-Mackensen & Mani, 2013)

#### Familiarisation

<table>
<thead>
<tr>
<th>Alternating trials</th>
<th>25 secs accumulated listening time to each</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passage 1 – End</td>
<td></td>
</tr>
<tr>
<td>Passage 2 – mid</td>
<td></td>
</tr>
</tbody>
</table>

#### Test

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

Segmentation demonstrated by any consistent difference in looking times to familiar and unfamiliar word-forms

sfrota@campus.ul.pt
Method

Lisbon Baby Lab

sfrota@campus.ul.pt
Measuring concurrent language abilities

EP version of the MacArthur Bates Communicative Development Inventory (CDI) short forms

http://labfon.letras.ulisboa.pt/babylab/pt/CDI/

(Frota et al. 2016)

sfrota@campus.ul.pt
Results - DS

✓ No clear evidence for segmentation
  Familiar vs. Unfamiliar: t(24)=1.9, p=.065, Cohen’s d=.38

✓ Overall, the DS group is not segmenting: no effect of the prosodic conditions
  $F(2,48)=0.8$, $p=.45$, $\eta^2=.03$

Fig. 1. DS Mean looking times (s) to edge, medial and unfamiliar.

sfrota@campus.ul.pt
Results - DS

- No age effect.
  - Two age groups (CDI age range): younger (below 18 mos, mean 12 mos) older (above 18 mos, mean 20 mos)

RM ANOVA: No effect of prosodic condition, no effect of age group ($F(1,23)=0.7, p=.39, \eta^2=.02$) and no interaction ($F(2,46)=0.7, p=.46, \eta^2=.01$).

However, medial > unfamiliar in younger, but edge > unfamiliar in older. Only edge vs. unfamiliar in older approached significance ($p=.08$)

Age as a continuous variable:
Im(LT ~ condition + Age in Months)
Condition, $F(2,71) < 1$; Age, $F(1,71) < 1$

Fig. 2. DS Mean looking times (s) to edge, medial and unfamiliar by age.
DS: Concurrent language skills

- Segmentation abilities correlated with the CDI expressive vocabulary score

Fig. 3. Correlation between looks to edge minus unfamiliar and the CDI vocabulary score (Pearson’s $r = .34$, $p = .05$).
Results - AR

✓ Evidence for segmentation
  Familiar vs. Unfamiliar: t(20)=2.9, p=.008, Cohen’s d=.66

✓ Evidence for segmentation in edge position!
  RM ANOVA: condition, $F(2,40)=9.64, p<.001, \eta^2=.32$;
  Post hoc, edge/unfamiliar $p=.008$, edge/medial $p=.03$, medial/unfamiliar $p=.99$

Fig. 4 AR Mean looking times (s) to edge, medial and unfamiliar.
Results - AR

- No age effect.
  - Two age groups (CDI age range): younger (below 18 mos, mean 11 mos) older (above 18 mos, mean 21 mos)
  - Age as a continuous variable:
    \[ \text{lm(LT} \sim \text{condition + Age in Months)} \]
    Condition, F(2,59)=5.53, p=0.006; Age, F(1,59) < 1

RM ANOVA: Main effect of prosodic condition, but no effect of age group (F(1,19)=1.69, p=.2, $\eta^2=.08$) or interaction (F(2,38)=1.74, p=18, $\eta^2=.08$). Same pattern of results across age groups.

Fig. 5. AR Mean looking times (s) to edge, medial and unfamiliar by age group.
Results

AR: Concurrent language skills

✓ Segmentation abilities correlated with receptive vocabulary (CDI)

More looks to edge  Better receptive vocabulary  More looks to medial  Lower receptive vocabulary

Fig. 4.

$\tau = .61, p = .01$

Fig. 5.

$r = -.49, p = .04$

sfrota@campus.ul.pt
Results

DS, AR and TD

**Effect of condition, group and interaction**

\[ \text{lmer}(LT \sim \text{condition} \ast \text{Group} + (1 | \text{Participant})) \]

Condition, \( F(2,172)=18.5, p<.001 \);
Group, \( F(2,86)=8.1, p<.001 \);
Interaction, \( F(4,172)=2.9, p=.02 \)

Within AR: familial risk and preterm

**Effect of condition, No interaction**

RM ANOVA: Condition, \( F(1.88, 30.06)=6.42, p=.005 \);
Group, \( F(1,16)=4.45, p=.05 \);
Interaction, \( F(1.88, 30.06) <1 \)

sfrota@campus.ul.pt
Discussion

- Prosody drives early segmentation skills!
  - Segmentation is seriously delayed and follows a different developmental path in DS babies
  - AR babies successfully segmented at the **prosodic edge** only
  - Although following the TD developmental path, no emergence of segmentation in medial position yet. Segmentation abilities are delayed in the AR group

- Prosody modulated the relation between segmentation abilities and lexical knowledge
  - A link between segmentation skills and language acquisition, that had not yet been found for atypical development.

- Implications for remediation/intervention strategies
- Future research: focus on sub-groups of at risk babies
Thank you!
Obrigada!

@lisbonbabylab

sfrota@campus.ul.pt
http://labfon.letras.ulisboa.pt/babylab/

PTDC/MHCLIN/3901/2014, PTDC/LLTLIN/29338/2017