Explorations on word prominence in a language with contrastive stress: adult and infant data

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Introduction

■ Word prominence is a prosodic dimension that varies across languages
  – Properties of stress in the phonological grammar: variable stress (Catalan, English, Spanish, Russian) / fixed stress (French, Finnish, Polish, Turkish)
  – Correlates of stress: particular cues (pitch, duration, intensity, vowel quality), the weighting of cues for stress prominence

■ Word prominence plays a key role
  – Phonological organization of prosody
  – Language processing
  – Language acquisition
Introduction


- **Constrains** lexical access, word recognition/identification [Cooper et al. 2002, Cutler 2005, Soto et al. 2001]

- **Facilitates** language acquisition: segmentation of the speech signal in words, word categorization [Jusczyk et al. 1999, Nazzy et al. 2006, Polka & Sundara 2012, Shi et al. 2006]
There is a vast literature on the perception of word prominence, in particular comparing languages.

- However, reported findings are not always convergent (e.g., primary cue for stress in English, Chrabaszcz et al. 2014).
- Important claims need to be tested (e.g., stress ‘deafness’ as the result of a fixed stress grammar, Peperkamp et al. 2010).
- Studies on typologically diverse languages (phonological and prosodic grammar, cues for stress prominence) are scarce.

Perception of word prominence in European Portuguese (EP)

- Uncommon combination of prosodic properties
- Uncommon combination of cues for word stress
Overview

1. Previous research on the perception of word prominence: adults and infants
2. Why European Portuguese (EP) ?
   • Word prominence in EP
3. Experimental studies: Adult perception
   • Experiment 1: ABX discrimination
   • Experiment 2 & 3: Sequence recall tasks
   • Experiment 4: ERP (MMN)
   • Experiment 5: ABX discrimination
   • Discussion
4. Experimental study: Infant perception (ET)
5. General discussion
1. Previous research: Adults

- Difference in perceptual abilities between speakers of languages with unpredictable/variable stress (stress can be used to contrast words) and speakers of languages with predictable/fixed stress

<table>
<thead>
<tr>
<th>Stress</th>
<th>Unpredictable/variable</th>
<th>Predictable/fixed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor or Stress ‘deafness’</td>
<td>✗</td>
<td>✓ French, Finnish, Hungarian, Polish, Turkish (varying degrees: domain, lexical use, lexical exceptions, e.g. Polish weak effect)</td>
</tr>
<tr>
<td>No stress ‘deafness’</td>
<td>✓ Catalan, English, Spanish, Russian (with differences)</td>
<td>✗</td>
</tr>
</tbody>
</table>

Dupoux et al. 1997, 2001; Luyanchenko et al. 2011; Peperkamp & Dupoux 2002; Peperkamp et al. 2010; Ortega-Llebaria 2010
1. Previous research: Adults

- Correlates of word prominence vary and combine in language-specific ways, but duration seems to be a robust cue for stress across languages.
  - Suprasegmental cues: duration, intensity, pitch
  - Segmental cues: vowel quality, spectral tilt

Catalan, Dutch, English, Spanish speakers perceive words contrasting in stress (in the absence of pitch accents, irrespective of segmental cues) > **duration** influences perception of word prominence across languages.

1. Previous research: Adults

- **Claim:** Perception of word prominence is prosodically-based (duration), independently of the language use of segmental cues to stress (Ortega-Llebaria et al. 2010)

- Two main **predictions:**

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<tbody>
<tr>
<td>Stress ‘deafness’ effect</td>
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<td>Correlates of stress</td>
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1. Previous research: Infants

- Difference across languages in the development of infants’ perception of word prominence

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<tbody>
<tr>
<td>Discrimination limited variation</td>
<td>✔ At 6 mos Spanish</td>
<td>✔ At 6 mos French</td>
</tr>
<tr>
<td>Discrimination segmental variation</td>
<td>✔ after 6 mos if native English, Spanish (e.g., Skoruppa et al. 2011, 2013)</td>
<td>✗ French (e.g., Skoruppa et al. 2013)</td>
</tr>
<tr>
<td>Preference/Asymmetry</td>
<td>✔ After 4-6 mos Dutch, English, German &gt; Trochaic ✗ Catalan, Italian, Spanish</td>
<td>✔ After 4-6 mos, French &gt; Iambic (or ✗ NO preference)</td>
</tr>
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1. Previous research: Infants

- Two main predictions:

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- Properties of stress in the native phonological grammar
- Other prosodic properties of the language (Rhythm-based hypothesis, Nazzi et al. 2006)
- Frequency patterns: distribution of trochaic and iambic words
2. Why EP?

- **EP has variable stress** (=Catalan, Spanish, English)
  - Stress may fall within the last 3 syllables of the prosodic word
  - Stress is **lexically contrastive**: *bambo* [ˈbɔ̃bu] / *bambu* [bɔ̃ˈbu], 'lax' / 'bamboo'; *explicito* [ʃˈplisitu] / *explicito* [ʃpliˈsitu], 'explicit' / 'I make explicit'

- **Correlates of stress – diverse set of cues**
  - Suprasegmental cues: **Duration** (=Spanish, Catalan), low co-variation between stress and pitch accents (≠Spanish, Catalan, English)
  - Segmental cues: Vowel quality > **reduction of unstressed vowels** (=English, Catalan) /i, e, ɛ, a, o, ɔ, u/ > [i, i, ɛ, u]

General phenomenon with exceptions
2. Why EP?

- EP has **variable stress** (=Catalan, Spanish, English)
- Correlates of stress – diverse set of cues (=Cat, Eng)
  - **Uncommon combination**: longer duration in stressed syllables, vowel reduction in unstressed syllables, low co-variation stress/accent (most stressed syllables unaccented)
- Frequency data (disyllabic words, % trochaic)
  - English 74%, 78%; **EP** 66%, 74%; Spanish 60%~70% (Pons & Bosch 2010; FrePoP database http://frepop.letras.ulisboa.pt)
- Rhythm - **Mixed properties**
  - Combines Germanic & Romance features: mix of stress-timed and syllable-timed rhythm, however **NOT** perceived as a stress-timed language (Frota et al. 2001, 2002)
2. Why EP?

Previous studies on the perception of word prominence

- **Duration** – main cue
  - Stress identification in the absence of vowel reduction:  
    
    $\text{['plisitu] 'explicit'}$ $\text{[plisitu] 'I make explicit'}$
    
    (Delgado Martins 1977, 1986)

- Effects of *vowel quality*
  - Full vowels tend to be identified as stressed (Castelo 2005)

- No infant studies
  - Infants & toddlers sensitive to stress location in a word learning study: $\text{[m\text{ilu}] / [mi‘lu]}$ (Frota et al. 2012)
2. Why EP?

- Predictions I

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<td>Correlates of stress</td>
<td>✓ Suprasegmental cues (duration), e.g., Spanish</td>
<td>✓ Suprasegmental cues (duration), e.g., Catalan</td>
</tr>
</tbody>
</table>

Perception of word prominence is prosodically-based (duration), as previously claimed.

If suprasegmental cues are not enough (language-sensitive mechanism in stress perception):

EP > new data contributing to the understanding of the role of prosodic cues alone in stress perception, as well as of vowel quality cues.
2. Why EP?

- Predictions II

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<tr>
<td></td>
<td>Unpredictable/variable stress</td>
<td>Stress-timed languages &gt; trochaic preference</td>
</tr>
<tr>
<td></td>
<td>Predictable/fixed stress</td>
<td>Syllable-timed languages &gt; NO trochaic bias, NO preference</td>
</tr>
</tbody>
</table>

Frequency data would favour the trochaic pattern (closer to English than Spanish)

EP > new data contributing to the understanding of the role of native phonological grammar, rhythm (and frequency) in how stress perception develops in language acquisition
2. Why EP?

- Research questions
  - To what extent is the stress ‘deafness’ effect a result of a fixed stress grammar (Peperkamp et al. 2010), or is the language-particular combination of cues the key factor?
  - Is perception of word prominence universally based on suprasegmental cues (duration) independent of language use of segmental cues (Ortega-Llebaria et al. 2010)?
  - What language-specific factors shape early perception of stress?
3. Experimental studies
Adult perception – Exp 1: ABX

Correia, Butler, Vigário & Frota 2015. Language and Speech

- **ABX discrimination task:** Same experimental procedure as in Dupoux et al.'s (1997) Experiment 1 (Comparison with results for French and Spanish)

- **Materials:** 15 pairs of disyllabic nonsense words with penult and final stress. Suprasegmental cues the *only* cues to stress, e.g., [ˈmipu] / [mipu], [ˈʃumi] / [ʃumi] (Citation forms)

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<th>Stressed syllables</th>
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<tbody>
<tr>
<td>NP M=251; SD=63</td>
<td>M=156; SD=56</td>
<td>p=.03</td>
</tr>
</tbody>
</table>

Acoustic analysis: Duration

- **Duration** and the **pitch fall** as cues to stress location. No segmental cues (vowel reduction)

Control condition: [ˈdɛsʊ]/[ˈdɛtu], [ˈsiɾu]/[ˈsɛɾu]

Pitch fall: H+L*
3. Experimental studies
Adult perception – Exp 1: ABX
Correia, Butler, Vigário & Frota 2015. Language and Speech

- Procedure: A, B (female speakers) X (male speaker), order counterbalanced within subjects (Dupoux et al. 1997)
  60 trials for stress contrast, 60 trials for phoneme control

- Participants: 16 standard EP native-speakers (undergraduate students). Order of stress/phoneme contrast counterbalanced between subjects

- Responses and RTs: SuperLab Pro v.4.5.

Significant main effect of type of contrast: error rate stress > phoneme
(F1(1,30) = 189.43, p < .001, $\eta^2 = .86$; F2(1,196) = 72.27, p < .001, $\eta^2 = .27$)

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<td>4%</td>
<td>21%</td>
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<tr>
<td>phoneme</td>
<td>3%</td>
<td>6%</td>
<td>5%</td>
</tr>
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3. Experimental studies
Adult perception – Exp 1: ABX

Correia, Butler, Vigário & Frota 2015. Language and Speech

Results and discussion:

- A stress 'deafness' effect similar to French
- EP speakers attend to prosodic cues less than Catalan speakers (Ortega-Llebaria et al. 2008, 2010)

Significant main effect of type of contrast: error rate stress > phoneme (F1(1,30) = 189.43, p < .001, $\eta^2 = .86$; F2(1,196) = 72.27, p < .001, $\eta^2 = .27$)

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3. Experimental studies
Adult perception – Exp 2: Sequence recall

Correia, Butler, Vigário & Frota 2015. Language and Speech

- **Sequence recall task**: Same procedure as in Dupoux et al.'s (2001, Experiment 4) - Comparison with results for French and Spanish, using an encoding task that accesses a more abstract processing level

- **Materials**: 2 pairs of disyllabic nonsense words (6 tokens of each wordx2sp) Suprasegmental cues the only cues to stress
  
  \[
  ['\text{numi}] / [\text{nu}\text{mi}] \\
  ['\text{mu}\text{p}ə] / [\text{mu}\text{nu}e]
  \]

  Control condition, phoneme contrast

---

**Acoustic analysis: Duration**

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<td>NP M=233; SD=28</td>
<td>M=166; SD=29</td>
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**Duration** and the **pitch fall** as cues to stress location. No segmental cues (vowel reduction)
3. Experimental studies
Adult perception – Exp 2: Sequence recall

Correia, Butler, Vigário & Frota 2015. Language and Speech

- **Procedure:** training phase to learn the association of each key [1] and [2] to each word, test trials of 5 token sequences, participants recall order of tokens in the sequence (Dupoux et al. 2001). 20 trialsx2. Ex: [ˈnumi]-[nuˈmi]-[nuˈmi]-[ˈnumi]-[nuˈmi]

- **Participants:** 12 standard EP native-speakers (undergraduate students). Order phoneme>stress contrast

- **Responses (Error rate):** SuperLab Pro v.4.5.

**Significant main effect of type of contrast:** error rate stress > phoneme (F(1,22) = 66.93, p < .001, $\eta^2 = .75$)

<table>
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<th>Sp</th>
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<td>89, 78%</td>
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<td>50, 34%</td>
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3. Experimental studies
Adult perception – Exp 2: Sequence recall

Correia, Butler, Vigário & Frota 2015. Language and Speech

Results and discussion:

- Again, a stress ‘deafness’ effect similar to French, using a method that taps into the phonological representation

Significant main effect of type of contrast: error rate stress > phoneme 
\[ (F(1,22) = 66.93, p < .001, \eta^2 = .75) \]

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3. Experimental studies

Adult perception – Exp 3: Sequence recall

Correia, Butler, Vigário & Frota 2015. Language and Speech

- **Sequence recall task:** Same procedure but with *vowel quality cues* added to the stress contrast stimuli. Goal: test the effect of segmental cues (vowel reduction)

- **Materials:** 2 pairs of disyllabic nonsense words (6 tokens of each word×2sp) 1. Suprasegmental cues AND segmental cues to stress > [e] vs. [i]  
  [ˈne mi] / [ˈniˈmi]  
  Control condition, phoneme contrast  [ˈmu pe] / [ˈmuˈne]

Acoustic analysis: Duration

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*Duration, pitch fall and vowel quality* as cues to stress location

Pitch fall: H+L*
3. Experimental studies
Adult perception – Exp 3: Sequence recall

Correia, Butler, Vigário & Frota 2015. Language and Speech

- **Procedure:** Same as in Experiment 2.
  Ex: ['ne mi]-[ni\textipa{\textprime}mi]-[ni\textipa{\textprime}mi]-['ne mi]-[ni\textipa{\textprime}mi]

- **Participants:** 12 standard EP native-speakers (undergraduate students). Order phoneme>stress contrast

- **Responses (Error rate):** SuperLab Pro v.4.5.

No significant effect of type of contrast in citation form (NP): error rate stress ≡ phoneme ( $t(11) = .07, p = .4$ )

Significant diff. Exp 2 and 3 for stress ($t(22) = 4.98, p < .001$, not for phoneme ($t(22) = .04, p = .97$).

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3. Experimental studies
Adult perception – Exp 3: Sequence recall

Correia, Butler, Vigário & Frota 2015. Language and Speech

Results and discussion:

- Vowel reduction prevents the stress ‘deafness’ effect previously found > vowel quality as the key correlate for stress (unlike Catalan)
- Only with prosodic cues alone, EP approximates fixed stress languages like French

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### Perception of word prominence

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</table>

Perception of word prominence is prosodically-based (duration), as previously claimed.

If suprasegmental cues are not enough (language-sensitive mechanism in stress perception),

- No Stress ‘deafness’ (vs. French)
- Stress ‘deafness’ (French)
3. Experimental studies
Adult perception – interim summary

Perception of word prominence

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Perception of word prominence is prosodically-based (duration), as previously claimed.
If suprasegmental cues are not enough (language-sensitive mechanism in stress perception)

EP > now data strongly suggesting a language-sensitive mechanism in stress perception (vs. typological grouping or universal prosodic basis)
3. Experimental studies
Adult perception – Exp 4: ERP (MMN)

- Passive oddball paradigm: Investigate if EP speakers can unintentionally discriminate stress patterns

- Materials: CVCV nonsense words with trochaic (penult) and iambic (final) stress without vowel reduction. $[^{\prime}bubu] / [bu^{\prime}bu]$ Two different tokens for each pattern. Acoustic onset differences were controlled (100ms)

- Procedure:
  - Trochaic block: iambic as standards
  - Iambic block: trochaic as standards
  - Within block 250 standards, 50 deviants
  - Total 600 trials
  - Visual stimuli: silent movie (The Gold Rush by Charlie Chaplin)
  - Comprehension questions after block

with Lu, Correia, Jerónimo & Vigário
3. Experimental studies
Adult perception – Exp 4: ERP (MMN)

Results (24 participants):

Main effect of Discrimination was significant for both trochee and iamb, but stronger for iamb (the negativity is more prominent than in the trochaic condition)
Results and discussion:

Speakers of EP were able to discriminate the two stress patterns without vowel reduction at the unintentional level > inconsistent with behavioral findings.

EP speakers appear to be more sensitive to the iambic than the trochaic stress pattern, against the frequency distribution of stress patterns in the language (e.g., Molczanow 2013 on Russian where results faithfully mirror frequency asymmetries).

Main effect of Discrimination was significant for both trochee and iamb, but stronger for iamb (the negativity is more prominent than in the trochaic condition).
3. Experimental studies
Adult perception – Exp 5: ABX

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- **ABX discrimination task:**
  - Replicate the findings from Exp 1 with the set of participants from the ERP experiment

- **Materials:** same as in Exp 1. Suprasegmental cues the **only** cues to stress, e.g., ['mipu] / [mi'pu], ['jumi] / [ju'mi] (Citation forms)

- **Procedure:** Similar to Exp. 1

- **Participants**
  - 21 EP speakers that also participated in the ERP experiment

- **Responses and RTs:** E-Prime 2.0
3. Experimental studies
Adult perception – Exp 5: ABX

Lu, Correia, Jerónimo, Vigário & Frota (in progress)

- **Results:**
  - Findings from Exp 1 **were replicated**: mean error rate 21.4%

<table>
<thead>
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<th>EP5</th>
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A difference was found between Iamb and Trochee with lower error rate when X=Iamb, both when X is equal or diff from the preceding stimuli.

Significant effect of proximity (F(1,19) = 4.61, p < .05, n² = .2) and of **identity of X** (F(1,19) = 18.87, p < .001, n² = .5), with no interaction between the two (F(1,19) < 1)

RTs: significant effect of **identity of X** (F(1,19) = 5.51, p < .05, η² = .23), Iamb faster.
3. Experimental studies
Adult perception – Exp 5: ABX

Lu, Correia, Jerónimo, Vigário & Frota (in progress)

Results:
- Reanalysis of Exp. 1 stress contrast data: Iamb/Trochee

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Analysis with Exp as a between subject factor: significant effect of identity of X (F(1,34) = 14.5, p < .01, $\eta^2 = .3$). No effect of experiment (F(1,34) = 1.44, p = .24, $\eta^2 = .04$). No interactions.

RTs: significant effect of identity of X (F(1,34) = 8.15, p < .01, $\eta^2 = .19$), Iamb faster.

The same trend in Exp. 1, with lower error rate when X=Iamb, both when X is equal or diff from the preceding stimuli.
3. Experimental studies
Adult perception – summary

- Summary:
  - Stress perception without vowel quality cues:
    - Behavioral findings > Stress ‘deafness’ effect in a language with variable stress; Prosodic properties alone were NOT enough to enable the perception of word prominence; however, perception of the Iambic pattern easier
    - ERP findings > discrimination (arguably at a more superficial acoustic level), stronger effect for iamb
  - Stress perception with vowel quality cues: NO stress ‘deafness’ effect

Acoustic level advantage in extract level of processing < Unless segmental cues

- YES for Iambs
- NO
- YES
4. Experimental studies
Infant perception – Exp 6: Eye-tracking

with Butler, Cortês, Correia, Vigário

- **Eye-Tracking:**
  - Version of the Anticipatory Eye Movement (AEM) paradigm to examine infants’ discrimination of stress (McMurray & Aslin 2004; Albareda-Castellot et al. 2011)

- **Materials:** Disyllabic *segmentally varied* nonsense words with penult and final stress, uttered by female speaker in CDS. Suprasegmental cues the *only* cues to stress,
  - e.g., ['milu] / [miˈlu], ['tɛnu] / [teˈnu] (Citation forms)

- **Participants:**
  - 24 infants from monolingual homes in the Lisbon area
  - (16 boys, mean age = 5 months 26 days, range 5 months 2 days – 6 months 28 days)
4. Experimental studies
Infant perception – Exp 6: Eye-tracking

with Butler, Cortês, Correia, Vigário

Procedure:

- **Training**: Infants' trained to associate each stress pattern with one image & side of the screen: 6 training trials (3 trochee, 3 iamb, pseudo-randomized; 4 nonsense words per trial)

- **Test**: Screen with two frames but no images while listening to novel tokens: 2 test trials (1 trochee, 1 iamb, counterbalanced)

Total of 8 blocks. Side/Image association to stress pattern counterbalanced between subjects
4. Experimental studies
Infant perception – Exp 6: Eye-tracking

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- Procedure (SMI RED500 eye-tracker):

  Discrimination: longer looking time to the target side
  Interaction between target side and stimuli > suggest a preference for one of
  the stress patterns
4. Experimental studies
Infant perception – Exp 6: Eye-tracking

Results: No difference in looking times to iambic/trochaic training trials, no other effects. **NO Discrimination**

- Proportional looking at the target and distracter trained sides

Window: 500ms after onset to 2000ms

ANOVA: no effect of target side ($F(1,20) = 1.53, p = .23, \eta^2 = .07$), order ($F(1,20) = 2.55, p = .13, \eta^2 = .11$) or stimuli ($F(1,20) < 1$), but a significant interaction between target side and stimuli ($F(1,20) = 5.85, p < .05, \eta^2 = .23$)

Discrimination: longer looking time to the target side

Interaction between target side and stimuli > suggest a preference for one of the stress patterns
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Results: Significant difference in looking to the iamb and trochee trained sides. Longer looking time to Iamb

Proportional looking at the Iamb and Trochee trained sides

Mean net dwell time (ms) to the lamb and Trochee trained sides, by Iambic and Trochaic test trials

Discrimination: longer looking time to the target side
Interaction between target side and stimuli > suggest a preference for one of the stress patterns
### Discussion:

#### Perception of word prominence

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<th>Unpredictable/variable stress</th>
<th>Predictable/fixed stress</th>
</tr>
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<td>Rhythm guides preferences</td>
<td>✓ Stress-timed languages &gt; trochaic preference</td>
<td>✗ Syllable-timed languages &gt; NO trochaic bias, NO preference</td>
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Frequency data would favour the trochaic pattern (closer to English than Spanish)
## 4. Experimental studies

### Infant perception – Exp 6: Eye-tracking

**with Butler, Cortês, Correia, Vigário**

- **Discussion:**

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Infant data is in line with adult findings on an advantage for iambics, by showing an early preference for this pattern in a language with variable stress.
5. General discussion

- Research questions (1)
  - To what extent is the stress ‘deafness’ effect a result of a fixed stress grammar (Peperkamp et al. 2010), or is the language-particular combination of cues the key factor?

Findings from 2 independent ABX tasks and a sequence recall task demonstrated a **stress deafness effect in a language with a variable stress grammar**, contra to previous results/claims.

Perceptual inability that emerges as a result of a mismatch

Input (variable) / speakers’ phonological representation of stress (fixed), e.g. French

Key correlates for stress in the input and in the native grammar, e.g. EP
5. General discussion

- Research questions (2)
  - Is perception of word prominence universally based on suprasegmental cues (duration) independent of language use of segmental cues (e.g., Ortega-Llebaria et al. 2010)?

EP findings (ABX, sequence recall) do NOT support the claims of prosodic based cross-linguistic perception of stress, contra previous results.

Language-specific basis for the perception of word prominence

- More driven by prosodic cues at the acoustic level (MMN, infant)
- Language-sensitive mechanism at more abstract processing levels (cue weighting)
5. General discussion

- **Research questions (3)**
  - What language-specific factors shape early perception of stress?

1. **Native phonological grammar:**
   - ✔ Variable stress language > later development of discrimination abilities based on prosodic cues, e.g. Spanish, English; Frota et al. 2012

2. **Rhythm & Frequency:**
   - ✔ Iambic preference > new finding in a variable stress language with mixed (but arguably) syllable-timed rhythm, contra frequency
   - ✖ When does the stress deafness effect emerge in development?
     - Adults: Iamb advantage
       - Bias to expect trochaic (but see Molczanow 2013)
       - Phrase-level prominence effect
     - Infants: Preference matches the familiar native language pattern!
5. General discussion

- Research questions
  - To what extent is the stress 'deafness' a result of a fixed segmental stress system (Peperkamp et al. 2010), or is the language-particular combination of suprasegmental cues the key factor?
  - Is perception of word prominence universally based on suprasegmental cues (Ortega-Llebaria et al. 2010) independent of language use of segmental cues?
  - What language-specific factors shape early perception?
Thank you

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DEPE: PTDC/CLE-LIN/108722/2008
EBELa: EXCL/MHC-LIN/0688/2012
Explorations on word prominence in a language with contrastive stress: adult and infant data

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