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# *Early perception of lexical stress by European Portuguese learning infants*

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# Introduction

- This study focus on early perception of lexical stress
- Word stress 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
- Stress plays a central role
  - Phonological organization of prosody
  - Language processing, and **Language acquisition**

# Introduction

## Facilitates language acquisition:

Converging evidence on infants' early sensitivity to the prosodic properties of speech, suggesting infants are equipped with an input processing mechanism initially tuned to prosodic information (e.g. Morgan 1986, Morgan & Demuth 1996, Jusczyk 1997, Höhle 2009)

### Stress

- Segmentation of the speech signal into words (Jusczyk et al. 1999, Nazzi et al. 2006, Polka & Sundara 2012, Shukla et al. 2011)
- Segmentation of the speech signal into phrases (Bion et al. 2011; Christophe et al. 2003; Gout et al. 2004)
- Word categorization (Shi et al. 2006)
- Word-level and phrase-level meaning (Curtin 2009, 2010; Frota et al. 2012; Butler et al. 2015)
- Early marker of later language abilities (typical or impaired – Friedrich et al. 2009; Weber et al. 2005)

# Overview

1. Previous research on infant lexical stress perception
2. Stress in European Portuguese (EP)
   - Phonological grammar and Correlates of stress
   - Frequency patterns
   - Rhythmic properties
3. Method
   - Participants
   - Materials
   - Procedure
4. Results
5. Discussion

# 1. Previous research

- Difference across languages in the development of infants' perception of stress

| Stress | Unpredictable/variable | Predictable/fixed |
|---|---|---|
| Discrimination no variation | ✔ At 6 mos Spanish | ✔ At 6 mos French (but better sensitivity in bilinguals) |
| Discrimination with variation | ✔ after 6 mos ONLY if native English, German, Spanish | ✖ French |
| Preference/ Asymmetry | ✔ After 4-6 mos Dutch, English, German > Trochaic pattern | ✖ After 4-6 mos, French > NO preference |
| Preference/ Asymmetry | ✖ After 4-6 Catalan, Spanish NO preference | ✔ 6 in French/German-bilinguals, not 'syllable-based' |

Bijeljac-Babic et al. 2012, 2013; Friederici et al. 2007; Hohle et al. 2009; Jusczyk et al. 1993; Pons & Bosch 2007; Skoruppa et al. 2009, 2011, 2013; Weber et al. 2004

# 1. Previous research

- **Main finding**: perception of word stress is language-specific > grammar, rhythm, input frequency

| Perception of STRESS | | |
|---|---|---|
| Development of discrimination abilities | ✔ Unpredictable/variable stress | ✖ Predictable/fixed stress |
| Rhythmic-based (Nazzi et al. 2006) | ✔ Stress-timed languages > trochaic bias | ✖ Syllable-timed languages > NO trochaic bias, NO preference |
| Input frequency | ✔ Dutch, English, German (Trochaic>Trochaic) | ✖ Spanish (Trochaic> NO asym) French (Iambic > NO asym) |

- Perception develops as a function as the prosodic features of the native language

# 2. Stress in European Portuguese

1. EP has **variable stress** (=Catalan, Spanish, English)
   - Stress may fall within the last 3 syllables of the prosodic word
   - Stress is lexically contrastive: *bambo* [ˈbɐ̃bu] / *bambu* [bɐ̃ˈbu], 'lax' / 'bamboo'; *explícito* [ʃˈplisitu] / *explicito* [ʃpliˈsitu] , 'explicit' / 'I make explicit'
2. 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, ɨ, ɐ, u]

     General phenomenon with exceptions

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

# 2. Stress in European Portuguese

1. EP has **variable stress** (=Catalan, Spanish, English)
2. 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)
3. Frequency data (disyllabic words: % trochaic - token, type)
   - English 74%, 78%; **EP** 66%, 74%; Spanish 60%~70% (Pons & Bosch 2010; FrePoP database http://frepop.letras.ulisboa.pt)

CDS: 63%, 70%

4. 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)

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

- No previous infant studies
  - Infants & toddlers sensitive to stress location in a word learning study: ['**mi**lu] / [mi'**lu**] (Frota et al. 2012)

| Perception of STRESS | | |
|---|---|---|
| Development of discrimination abilities | ✔ Unpredictable/variable stress | ✖ Predictable/fixed stress |
| Rhythmic-based (Nazzi et al. 2006) | ✔ Stress-timed languages > trochaic bias | ✖ Syllable-timed languages > NO trochaic bias, NO preference |
| Input frequency | ✔ Dutch, English, German (Trochaic>Trochaic) ? | ✖ Spanish (Trochaic> NO asym) French (Iambic > NO asym) |

# 3. Method

- **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)

  6 infants excluded due to fussiness (2) and poor tracking (4)
- Why 5-6 months?
  - Discrimination with segmental variability not evident before 8 months, perhaps due to method sensitivity – eye tracking?
  - Preference/Asymmetry emerges after 4 months in some languages (between 4 and 6)
  - Language-specific perception in the pitch domain at 4-5 mos (Frota et al. 2014; Yeung et al. 2013)
  - Early marker of risk for later language impairments at 5 mos (Friedrich, et al. 2009; Weber et al. 2005)

# 3. Method

- All infants completed the CSBS-DP Checklist ( a developmental screening tool – Wetherby & Prizant 2003), adapted for Portuguese.

| N | Social composite | | Speech composite | | Symbolic composite | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| 24 | 10.83 | 2.82 | 3.29 | 1.33 | 3.71 | 1.90 | 17.83 | 4.79 |
| 50 | 10.00 | 2.95 | 3.74 | 1.76 | 4.32 | 1.48 | 18.06 | 4.70 |
| Cut-off | >7 | | >1 | | >2 | | >12 | |

A comparison with the means and SD in the English standardization sample:

All infants were showing social communication, language and symbolic functionning skills as expected for their age (including eye gaze, gestures, use of sounds and understanding)

# 3. Method

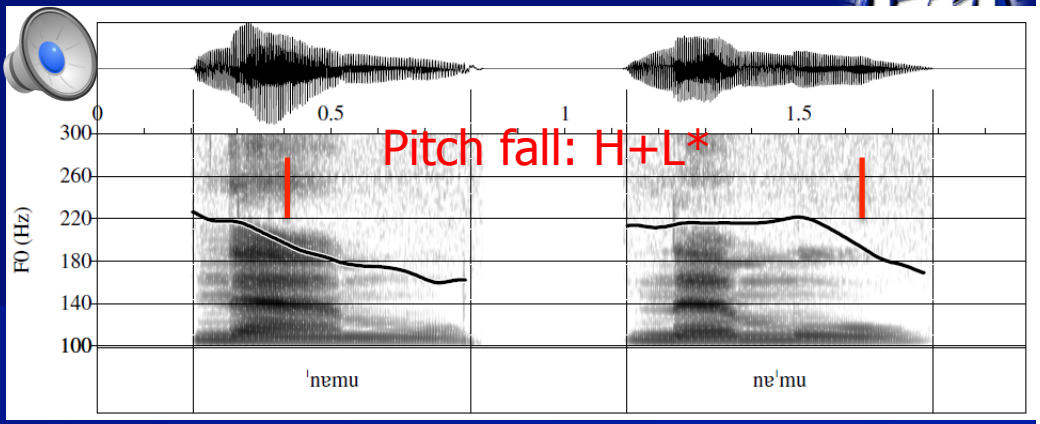
- **Materials:**
  - Disyllabic segmentally varied nonsense words with penult and final stress, uttered by female speaker in CDS. Suprasegmental cues the **only** cues to stress
    e.g., ['milu] / [mi'lu], ['tɐnu] / [tɐ'nu]  (Citation forms)

$$C_1V_1C_2V_2$$

  - Consonants were selected from the most-used consonants in Portuguese. Stops, fricatives and liquids were balanced. Both in training and testing there were 4 stops, 1 nasal, 1 fricative and 1 liquid. Within a trial, $C_1$ was different between words. $V_1$ ([ɐ] , [i] or [u]) was balanced across training and testing. $V_2$ was always [u].

# 3. Method

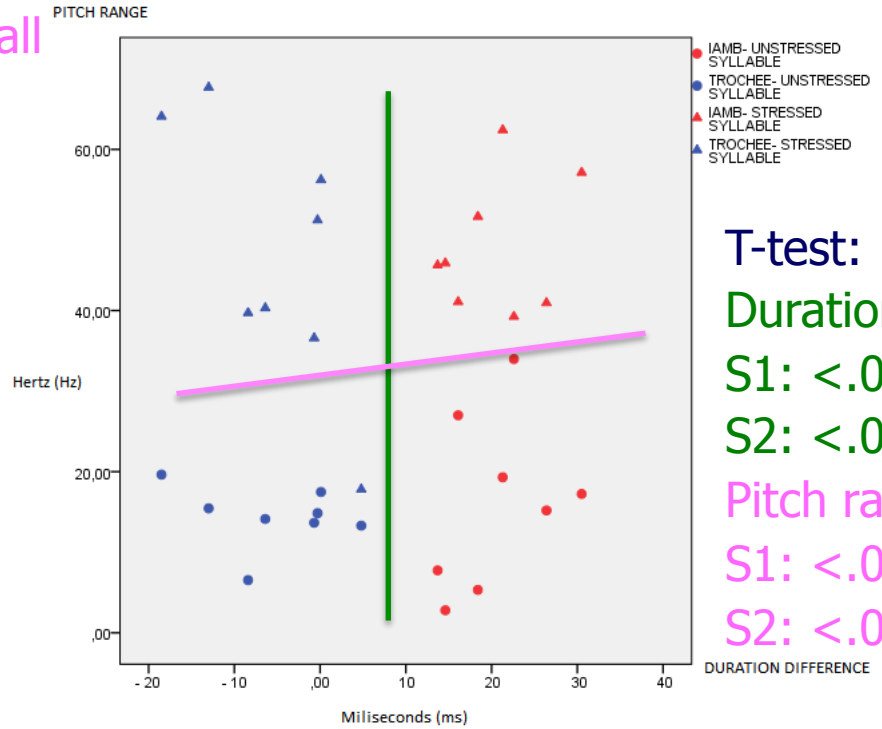
- **Materials:**




Trochee vs. Iamb Duration:S2-S1

Pitch fall

Unstressed vs. Stressed




T-test:

Duration

S1: <.001

S2: <.001

Pitch range

S1: <.001

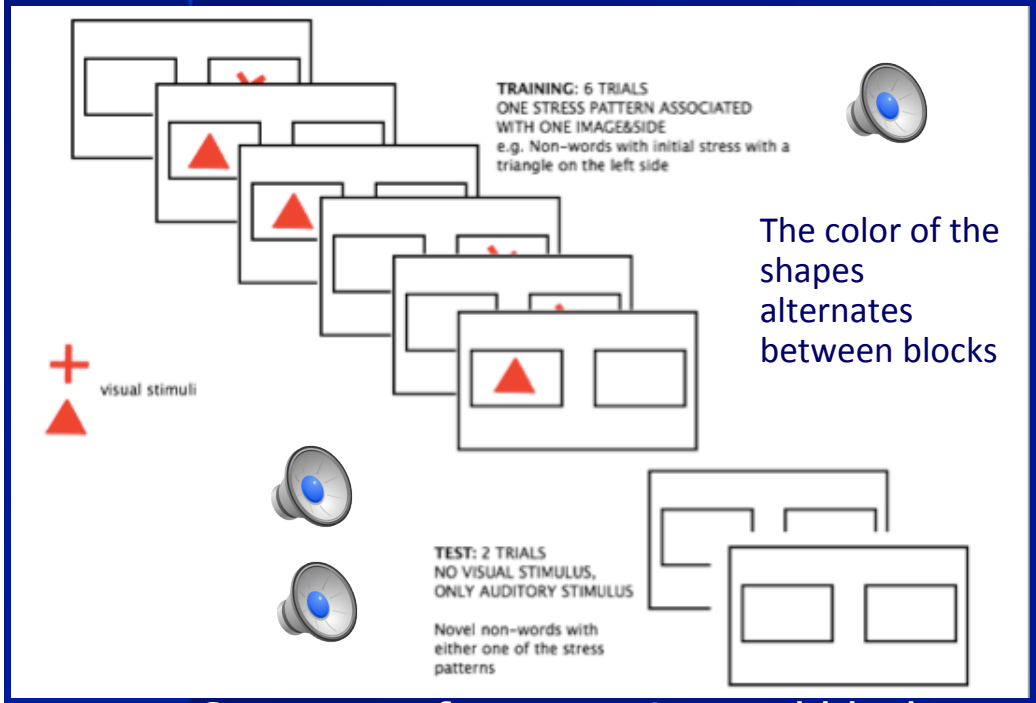
S2: <.001

Suprasegmental cues the **only** cues to stress:

Duration (stressed syllable longer) and location of the pitch fall

# 3. Method

- **Procedure:** Version of the **Antecipatory Eye Movement** (AEM) paradigm to examine infants' discrimination of stress (McMurray & Aslin 2004; Albareda-Castellot et al. 2011; Richardson & Kirkham 2004)




Structure of an experimental block

**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

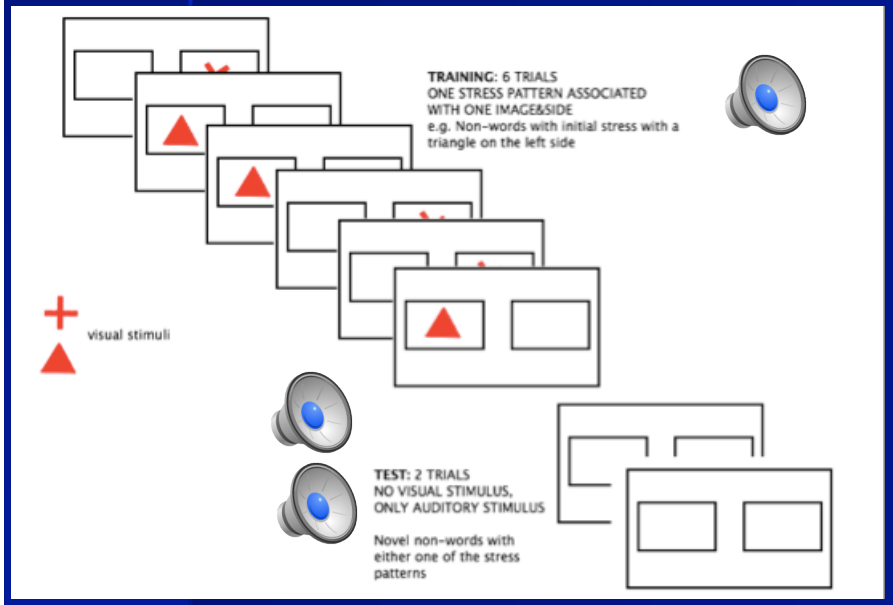
**Test**

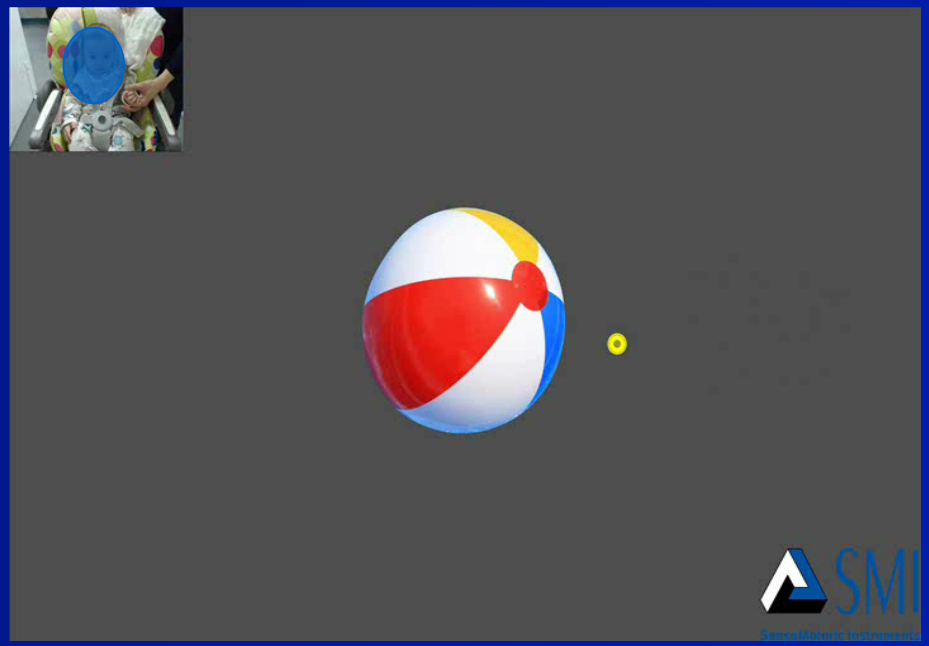
Screen with two frames but no images while listening to novel tokens: 2 test trials (1 trochee, 1 iamb, counterbalanced)

Total of 8 blocks. Side/Image association to stress pattern counterbalanced between subjects

# 3. Method

- **Procedure** (SMI RED500 eye-tracker):



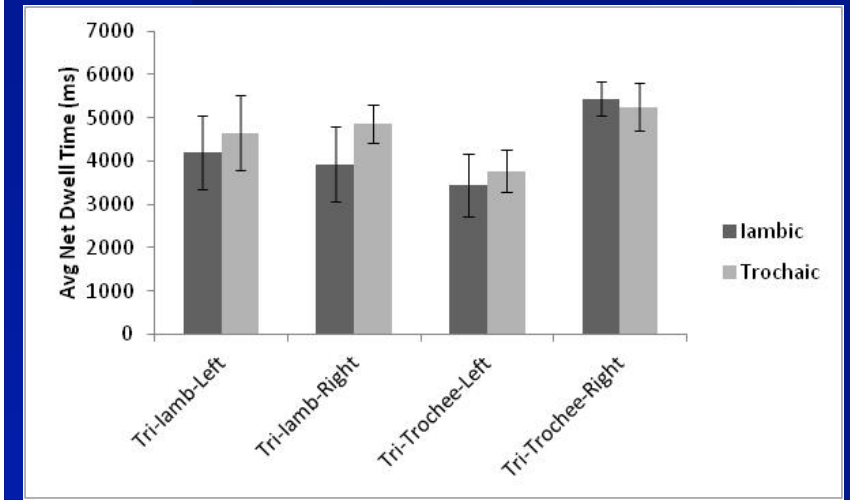




Discrimination: longer looking time to the target side

Interaction between target side and stimuli > suggest a preference for one of the stress patterns

# 4. Results

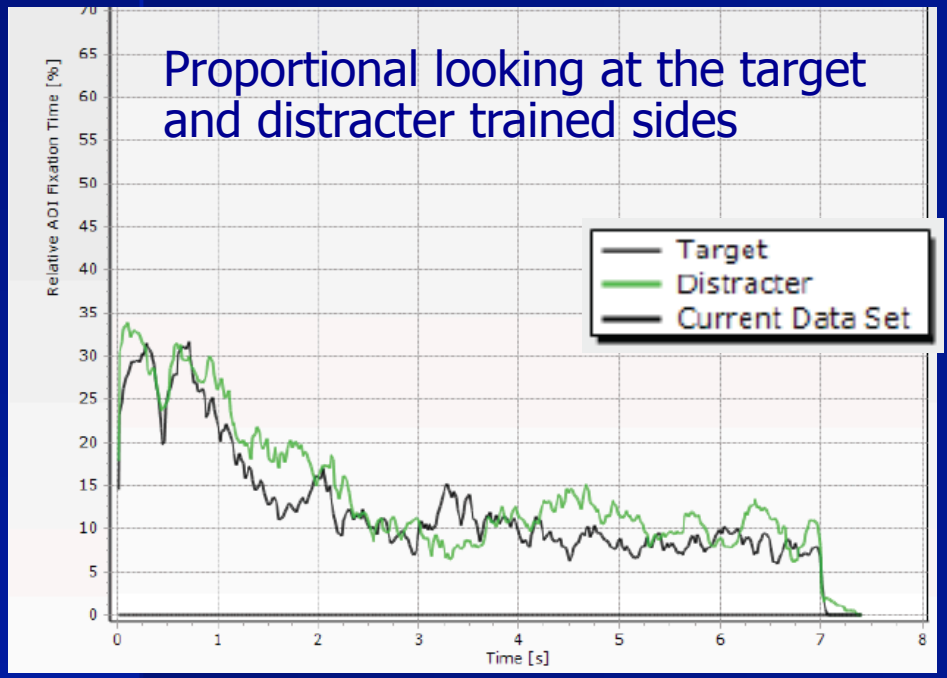
- Infants completed between 2 and 6 blocks (mean 4), between 3 and 12 test trials (mean 7.5)
- **Training phase** - Looking times to the image in the iambic and trochaic training trials were compared across the 4 counterbalancing conditions (tri-iamb-left, tri-iamb-right, tri-trochee-left, tri-trochee-right) > **No differences** found in looking between the two types of training trials (iambic/ trochaic) and no effect of the counterbalancing coundition.




ANOVA: **no effect of trained side** ($F(1,20) = 1.96$, $p = .18$, $\eta^2 = .09$) or counterbalancing $F(3,20) = 1.3$, $p = .18$, $\eta^2 = .09$), and no interaction ($F(3,20) < 1$)

# 4. Results: Test phase

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




Target side(2) X order(2) X stimuli(2)

Window: 500ms after onset to 2000ms

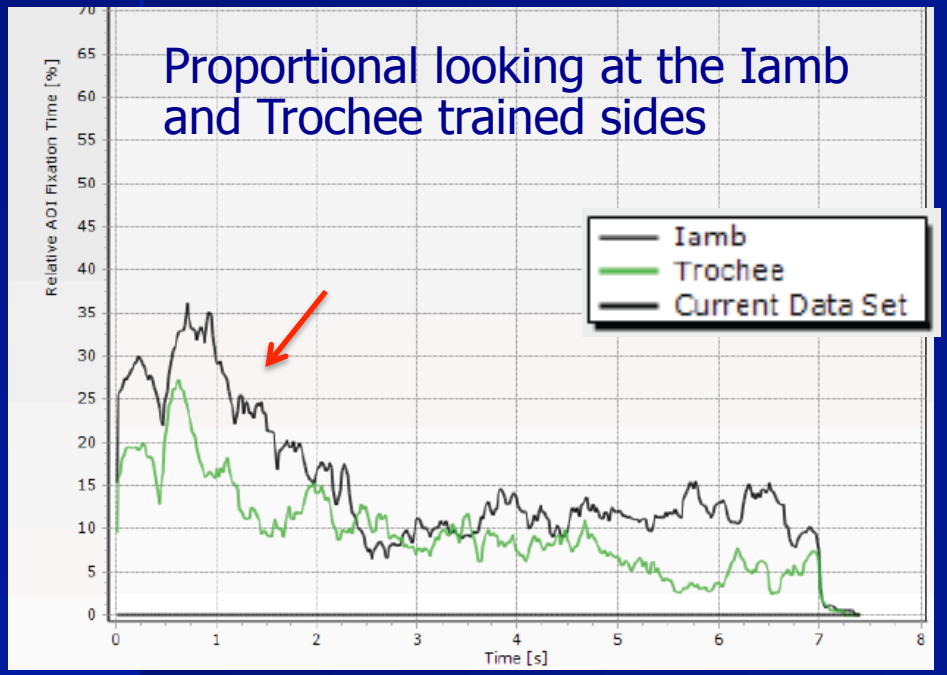
ANOVA: **no effect of target side** ($F(1,20) = 1.53$, $p = .23$, $\eta^2 = .07$), order ($F(1,20) = 2.55$, $p = .13$, $\eta^2 = .11$) or stimuli ($F(1,20) < 1$), BUT a significant interaction between target side and stimuli ($F(1,20) = 5.85$, $p < .05$, $\eta^2 = .23$)

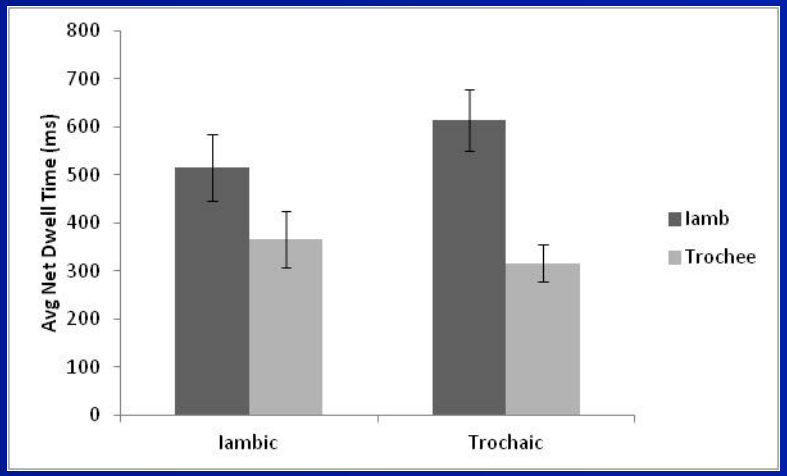
Discrimination: longer looking time to the target side

Interaction between target side and stimuli > suggest a preference for one of the stress patterns, possibly shown by an **asymmetry** in looking behavior

# 4. Results: Test phase

- Results: Significant difference in looking to the iamb and trochee trained sides. **Longer looking time to Iamb**




Mean net dwell time (ms) to the Iamb 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, shown by an **asymmetry** in looking behavior

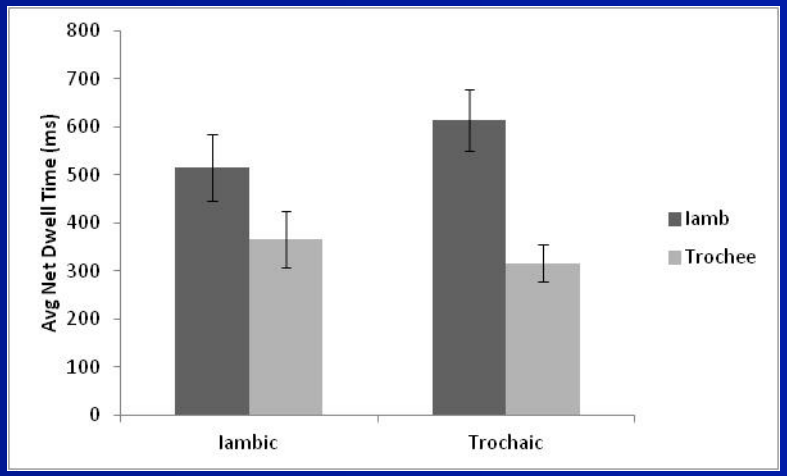
# 4. Results: Test phase

- Results: Significant difference in looking to the iamb and trochee trained sides. **Longer looking time to Iamb** (mean 578 vs. 366 for trochee)

Trained side(2) X order(2) X stimuli(2)

Window: 500ms after onset to 2000ms

ANOVA: **significant effect of trained side** ($F(1,20) = 5.7$, $p < .05$, $\eta^2 = .22$). No effects of order ($F(1,20) = 2.55$, $p = .13$, $\eta^2 = .11$) or stimuli ($F(1,20) < 1$), and no interactions




Mean net dwell time (ms) to the Iamb 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, shown by an **asymmetry** in looking behavior

# 5. Discussion

| | Perceptio… RESS | |
|---|---|---|
| Development of discrimination abilities | ✔ Unpredic… variable stress | ✖ Predictable/fixed stress |
| Rhythmic-based (Nazzi et al. 2006) | ✔ Stress-timed languages > trochaic bias | ✖ Syllable-timed languages > NO trochaic bias, NO preference |
| Input frequency | ✔ Dutch, English, German (Trochaic>Trochaic) | ? ✖ Spanish (Trocha… …ym) French (Iambic > … |

Later?

Iambic

✔ **Iambic bias** > **new finding (at 5 mos),** in a variable stress language with mixed (but arguably syllable-timed) rhythm, and a dominant trochaic input frequency pattern

# 5. Discussion

- Our findings confirm that asymmetries in stress perception emerge early (4-6) in development and are language-specific
- We add a new pattern to the previously described dichotomy between a *Trochaic preference* (stress-timed) and *No preference* (syllable-timed): **Iambic bias**
- This new finding is in line with two so far unrelated facts in the literature on EP
  - Early children's productions: (0;11-2;06) **σ > WS** (Correia 2009); more iambic targets attempted (Vigário et al. 2006)
  - Recent findings show an advantage for iambs in adult perception of stress (Lu et al., in progress)

# 5. Discussion

Infants: first develop the familiar native language pattern!

- What language-specific factors shape early perception of stress?

Native phonological grammar: → variable stress / fixed stress / stress domain

+

Rhythmic properties → Stress-timing, Syllable-timing, mix

+

Input frequency → Relative distribution of trochees and iambs (modulated by other factors)

+

Others ???

Iambic bias

Ambient language
Cluster of cues

Longer duration

Pitch fall

# ObriGAda

## Thank you

All infants and parents. The baby lab team: Cátia, Marisa, Cláudia

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EBELa: EXCL/MHC-LIN/0688/2012

## References


- Albareda-Castellot, B., Pons, F. & Sebastián-Gallés, N. (2011). The acquisition of phonetic categories in bilingual infants: new data from an anticipatory eye movement paradigm. Developmental Science, 14(2). 395-401.
- Bijeljac-Babic, R., Serres, J., Höhle, B. & Nazzi, T. (2012). Effect of Bilingualism on Lexical Stress Pattern Discrimination in French-Learning Infants. PLoS ONE 7(2). e30843.
- Bijeljac-Babic, R., Serres, J. Höhle, B. & Nazzi, T. (2013). Effect of Bilingualism on the Perception of Lexical Stress in 6-Month-Old French-Learning Infants. BUCLD 37 Proceedings, 24-35.
- Bion, A.H., Benavides-Varela, S. & Nespor, M. (2011). Acoustic markers of prominence influence infants' and adults' segmentation of speech sequences. Language and Speech, 54(1), 123-140.
- Butler, J., M. Vigário & S. Frota. (2015). Infants' perception of the intonation of broad and narrow. Language, Learning and Development.
- Christophe, A., Guasti, M. T., Nespor, M., & van Ooyen, B. (2003). Prosodic structure and syntactic acquisition: the case of the head-complement parameter. Developmental Science, 6, 213-222.
- Correia, S. (2009). The Acquisition of Primary Word Stress in European Portuguese. PhD Dissertation. University of Lisbon.
- Curtin, S. (2009). Twelve-month-olds learn word-object associations differing only in stress patterns. Journal of Child Language, 36, 1157-1165.
- Curtin, S. (2010). Young infants encode lexical stress in newly encountered words. Journal of Experimental Child Psychology,105, 376-385.
- Friederici, A. D., Friedrich, M., & Christophe, A. (2007). Brain responses in 4-month old infants are already language specific. Current Biology, 17, 1208–1211.
- Friedrich, M., Herold, B., & Friederici, A. D. (2009). ERP correlates of processing native and non-native language word stress in infants with different language outcomes. Cortex, 45, 662–676.
- Frota, S., Butler, J. & Vigário, M. (2014). Infants' perception of intonation: Is it astatement or a question? Infancy, 19(2), 194-213.
- Frota, S., M. Vigário, F. Martins & M. Cruz. Laboratório de Fonética (CLUL), Faculdade de Letras da Universidade de Lisboa. ISBN: 978-989-95713-2-7. ISLRN: 064-984-771-090-2 (http://frepop.letras.ulisboa.pt)

## References (cont.)


- Frota, S. & Vigário, M. (2001). On the correlates of rhythmic distinctions: the European/Brazilian Portuguese case. Probus 13, 247-273.
- Frota,S., Vigário, M. & Martins. F. (2002) Language Discrimination and Rhythm Classes: Evidence from Portuguese. In Proceedings of Speech Prosody 2002, Aix en Provence, 315-318.
- Frota, S., Butler, J., Correia, S., Severino, C. & Vigário, M. (2012) Pitch First, Stress Next? Prosodic Effects on Word Learning in a Intonation Language. Proceedings of the 36th annual Boston University Conference on Language Development edited by Alia K. Biller, Esther Y. Chung, and Amelia E. Kimball, 190-201. Somerville, MA: Cascadilla Press.Gout, A., Christophe, A. & Morgan, J. (2004). Journal of Memory and Language. 51. 548-567.
- Höhle, B. (2009) Bootstrapping mechanisms in first language acquisition. Linguistics, 47, 359-382.
- Höhle, B., Bijeljac-Babic, R., Herold, B., Weissenborn, J. & Nazzi, T. (2009) Language specific prosodic preferences during the first year of life: Evidence from German and French infants. Infant Behavior and Development, 32, 262-274.
- Jusczyk, P. (1997). The discovery of spoken language. Cambridge, MA: MIT Press.
- Jusczyk, P., Cutler, A., & Redanz, N. (1993). Preference for the predominant stress patterns of English worlds. Child Development, 64, 675-687.
- Jusczyk, P, Houston, D. & Newsome, M. (1999). The Beginnings of Word Segmentation in English-Learning Infants. Cognitive Psychology, 39. 159-207.
- McMurray, B. & Aslin, R. (2004). Anticipatory Eye Movements Reveal Infants' Auditory and Visual Categories. Infancy, 6(2). 203-229.
- Molczanow, J., Domahs, U., Knaus, J. & Wiese, R. (2013). The lexical representation of word stress in Russian: Evidence from event-related potentials. The Mental Lexicon, volume 8, number 2, pp. 164-194(31).
- Morgan, J., L. & Demuth, K. (1996). Signal to Syntax: Bootstrapping from Speech to Grammar in Early Acquisition. Mahwauh: L. Erlbaum Associates.
- Morgan, J. L (1986). From Simple Input to Complex Grammar. Cambridge, MA: MIT Press.

## References (cont.)


- Nazzi, T., Iakimova, G., Bertoncini, J., Fredonie, S., & Alcantara, C. (2006). Early segmentation of fluent speech by infants acquiring French: Emerging evidence for crosslinguistic differences. Journal of Memory and Language, 54(3), 283-299.
- Ortega-Llebaria, M., del Mar Vanrell, M., & Prieto, P. (2010). Catalan speakers' perception of word stress in unaccented contexts. Journal of the Acoustical Society of America, 127(1), 462–471.
- Peperkamp, S., Vendelin, I. & Dupoux, E. (2010). Perception of predictable stress: A cross-linguistic investigation. Journal of Phonetic, 38(3), 422-430.
- Polka, L. & Sundara, M. (2012). Word Segmentation in Monolingual Infants Acquiring Canadian English and Canadian French: Native Language, Cross-Dialect, and Cross-Language Comparisons. Infancy, 17(2). 198-232.
- Pons, F., & Bosch, L. (2007). The perception of lexical stress patterns by Spanish and Catalan infants. In P. Prieto, J. Mascar, & M.J. Sol (Eds.), Segmental and prosodic issues in Romance phonology, CILT 282 (pp. 199–218). Amsterdam: John Benjamins.
- Pons, F. & Bosch, L. (2010). Stress Pattern Preference in Spanish-Learning Infants: The Role of Syllable Weight. Infancy, 15(3). 223-245.
- Shi, R., Cutler, A., Werker, I. 81 Cruickshank, M. (2006). Frequency and form as determinants of functor sensitivity in English-acquiring infants. Journal of the Acoustical Society of America, 119: EL61—EL66.
- Shukla, M., White, K. & Aslin, R. (2011). Prosody guides the rapid mapping of auditory word forms onto visual objects in 6-mo-old infants. PNAS, 108(15).
- Skoruppa, K., Pons, F., Christophe, A., Bosch, L. Dupoux, E., Sebastián-Gallés, N., Limissuri, R. A. & Peperkamp, S. (2009). Language-specific stress perception by 9-month-old French and Spanish infants. Developmental Science, 12(6), pp. 914–919.
- Skoruppa, K., Cristià, A., Peperkamp, S., Seidl, A. (2011). English-learning infants' perception of word stress patterns. Journal of the Acoustical Society of America, 130(1), EL50-EL55.

## References (cont.)


- Skoruppa, K., Pons, F., Bosch, L., Christophe, A., Cabrol, D. & Peperkamp, S. (2013). The development of word stress processing in French and Spanish infants. Language Learning and Development, 9(1), 88-104. 6038-6043.
- Vigário, Freitas, M. J. & Frota, S. (2006) Grammar and frequency effects in the acquisition of prosodic words in European Portuguese. Language and Speech (Special Issue Crosslinguistic Perspectives on the Development of Prosodic Words, guest-edited by K. Demuth) 49(2), 175-203.
- Weber, C., Hahne, A., Friedrich, M. & Friederici, A. (2004). Discrimination of word stress in early infant perception: electrophysiological evidence. Cognitive Brain Research, 18. 149-161.
- Weber, C., Hahne, A., Friedrich, M. & Friederici, A. (2005). Reduced stress pattern discrimination in 5-month-olds as a marker of risk for later language impairment: Neurophysiologial evidence. Cognitive Brain Research, 25. 180-187.
- Yeung, Chen & Werker (2013). When does native language input affect phonetic perception? The precocious case of lexical tone. Journal of Memory and Language, 68, 123-139