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Infants' perception of pitch-based prosodic contrasts

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Introduction

- There is a vast literature 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)
- Prosody helps to bootstrap the learning of language
  - stress, prominence, boundaries, rhythm, tone, intonation
    - Segment the speech signal: word segmentation (Mersad et al. 2010, Shukla et al. 2011), phrase segmentation (Johnson & Seidl 2008, Bion et al. 2011)
    - Word categorization (Shi et al. 2006); Word order (Christophe et al. 2003)
    - Word-level meanings (tone languages), and phrase-level meanings: sentence types, focus

Introduction

- Infants' ability to distinguish between forms of phonetic variation in speech that are *relevant to meaning* is essential for their language development.
- Acquisition of sound categories: developmental change before the infant's first birthday
  - Decline in discrimination of non-native contrasts
  - Stable discrimination or sensitivity gains for native contrasts

  (e.g., Kuhl 2004, Saffran et al. 2006, Narayan et al. 2010)
- The infant's task in learning a language involves a stronger commitment to the native language as development proceeds (NLNC hypothesis, Kuhl & Rivera-Gaxiola 2008, Gervain & Mehler 2010)

Introduction

- Although the functions of prosody are quite general across languages, prosodic cues are language-specific
  - stress: pitch (Polish), duration (Welsh, Russian), vowel quality (EP)
  - prosodic boundaries: pitch, duration (English), pauses (Dutch)
  - questions: rising pitch (EP), low pitch (Chickasaw), peak alignment (Neapolitan Italian), peak height (Japanese), duration (Nateni)
  - focus: peak height (English), suspension of downdrift (Japanese), peak alignment (EP)
  - lexical tones: rising, falling (Mandarin), high, low (Yoruba)
- Investigate infants' perception of native (and non-native) prosodic contrasts (which prosodic cues are attended to and when, that may provide useful information to meaning and the acquisition of other aspects of language)

Introduction

Early perception of prosodic contrasts in the presence of segmental variability:
Protracted development for stress vs. precocious abilities for lexical pitch

- Previous studies on the development of infants' perception of prosodic contrasts focused on acquisition of lexical properties

Lexical	Limited variation	Segmental variation
Stress	✔	✖ only after 6 mos & native (e.g., Skoruppa et al. 2013)
Pitch accent		✔ as early as 4 mos, for Japanese learners (Sato et al., 2009)
Tone	✔ as early as 4 mos, but only tone learners > 6 mos, unless very salient (Mattock & Burnham, 2006; Yeung et al, 2013; Liu & Kager, 2014)	✖? only after 6 months, native (Shi, 2010)

Introduction

Early sensitivity to pitch-based contrasts, which is largely independent from ambient language effects.

- Recent research suggests that infants' perception of prosodic cues may depend on the nature of the cues, with pitch-based contrasts being processed differently and earlier than duration-based differences
  - Infants at 7 months group syllables with variable pitch based on a high-low pitch pattern, but no grouping was found when duration differs between syllables, unlike in adults (Bion et al. 2011).
  - Human infants and nonhumans group sound sequences into trochaic patterns based on pitch, but do not use duration as a cue to group sequences in iambic structures (<8 months), unlike human adults (de la Mora et al. 2013, Yoshida et al. 2010).
- Pitch-based discrimination is more dependent on general perceptual abilities, whereas discrimination of duration contrasts is more dependent on language experience

Introduction

- Intonation is the use of prosodic features, namely pitch, to encode linguistic information > Little is known about the developmental course of infants' perception of intonation (3 studies on English, conflicting results)
- Like lexical pitch, intonation varies across languages and impacts upon meaning. Unlike lexical pitch, intonation conveys phrasal meanings, like sentence type and pragmatic distinctions.
- In intonation (as in lexical pitch), a variety of pitch cues can be used to signal meaning: e.g., pitch height, pitch direction, pitch register, pitch timing (temporal location of pitch turning points)

Introduction

- Research questions
  - Does early perception of intonation support precocious discrimination abilities for pitch (as found in previous work), or does the nature of the pitch cues matter?
  - To what extent is early sensitivity to pitch-based contrasts independent from the native language (as suggested in recent work)?

- Series of experiments examining infants' discrimination of native and non-native pitch-based prosodic contrasts, in the first year of life.

Overview

1. Method: Procedure used in all 4 experiments
2. Native discrimination of intonational contrasts (EP)
   - Experiment 1: Statement vs. Yes-no question
   - Experiment 2: Broad vs. Narrow focus
   - Discussion
3. Non-native discrimination of pitch-based contrasts
   - Experiment 3: English-learning infants' perception of the EP sentence type distinction
   - Experiment 4: EP-infants' perception of a lexical tone sequence contrast
   - Discussion
4. General discussion

H+L* L%/H+L* LH%

H+L* L%/H*+L L%

H+L* L%/H+L* LH%

Mandarin T1+T4 vs. T1+T2

Overview

1. Method: Procedure used in all 4 experiments
2. Native discrimination of intonational contrasts (EP)

   Similar discrimination pattern
   ⇩
   precocious abilities for pitch

   H+L* L%/H+L* LH%

   H+L* L%/H*+L L%

3. Non-native discrimination of pitch-based contrasts

   Early discrimination
   ⇩
   Early sensitivity independent from the native language

   H+L* L%/H+L* LH%

   Mandarin tones 14 vs. 12

4. General discussion

Overview

1. Method: Procedure used in all 4 experiments
2. Native discrimination of intonational contrasts (EP)

Different discrimination pattern

↓

≠ cues, ≠ developmental paths

H+L* L%/H+L* LH%

H+L* L%/H*+L L%

3. Non-native discrimination of pitch-based contrasts

Late/No discrimination

↓

Early language-specific effects

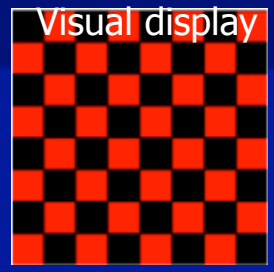
H+L* L%/H+L* LH%

Mandarin tones 14 vs. 12

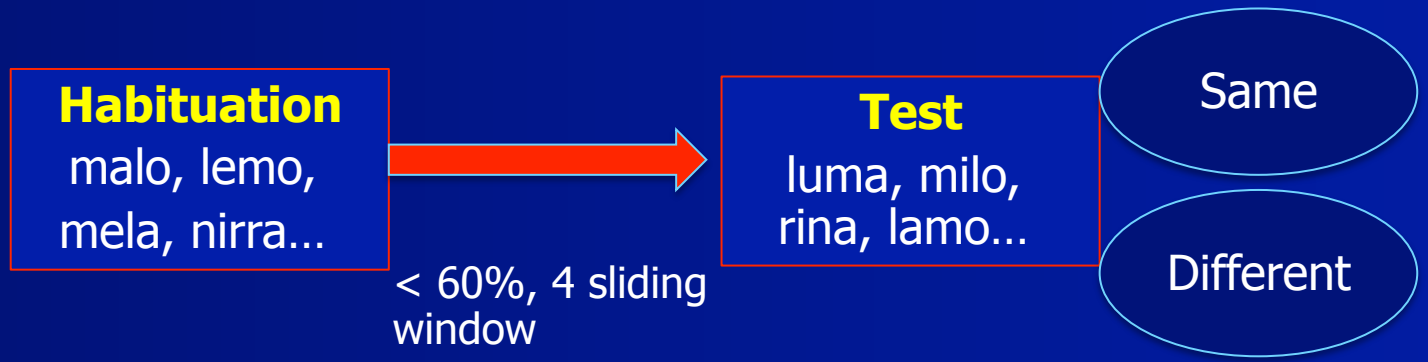
4. General discussion

1. Method

- Procedure



- Modified version of the visual habituation paradigm (Stager & Werker, 1997)



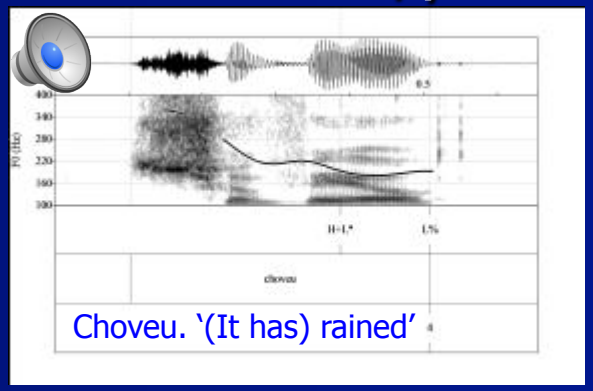
- Looking times to visual display were recorded and compared
- If sensitive to the prosodic contrast, infants should display longer looking times to the switch (different) trials

Lisbon Babylab Visual Habituation Paradigm

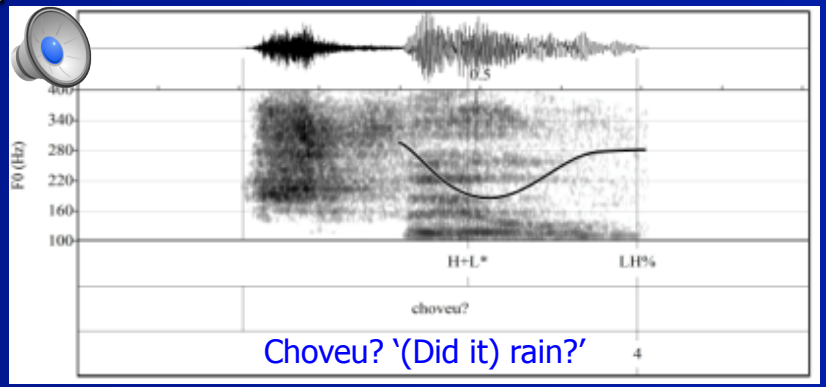
2. Native discrimination: Exp. 1

Frota, Butler & Vigário 2014. Infancy, 19(2), 194-213

- The statement/yes-no question distinction



Choveu. '(It has) rained'

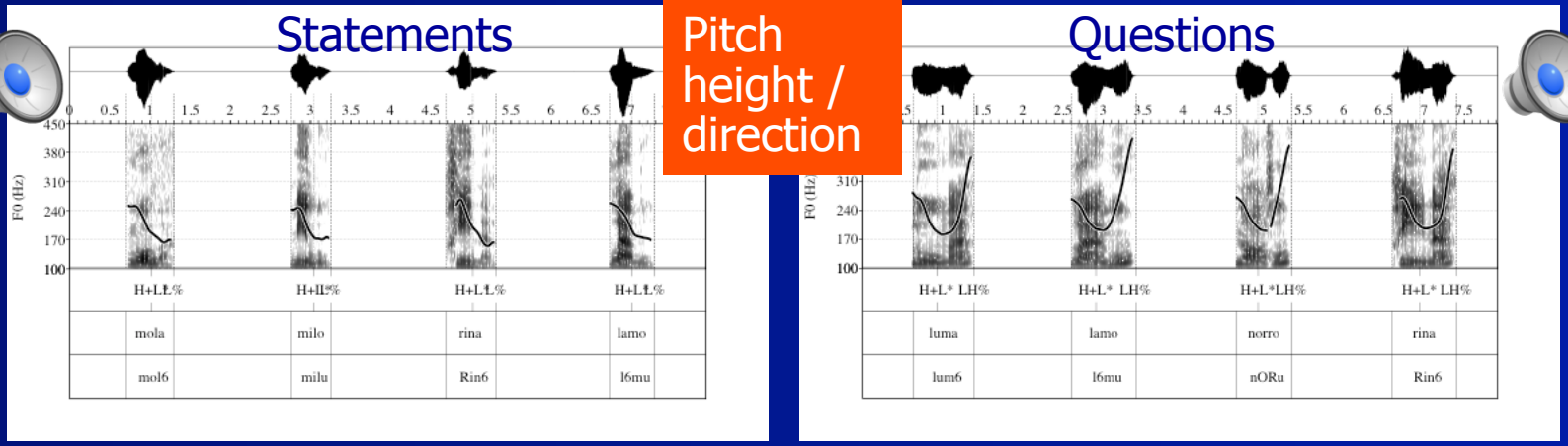


Choveu? '(Did it) rain?'

  - Yes-no questions are string identical to statements (Mateus et al. 2003)
  - Main cue final pitch: statement: H+L***L%**; question: H+L***LH%**
  - Longer durations of nuclear and post-nuclear syllables in questions
  - Higher first peak in questions is optional (Frota 2002)
  - The prosodic contrast is perceived by adult native speakers (Falé & Faria 2005)

2. Native discrimination: Exp. 1 statement/yes-no question

- Materials: Segmentally varied one pseudo-word utterances produced by a female native speaker in infant-directed speech



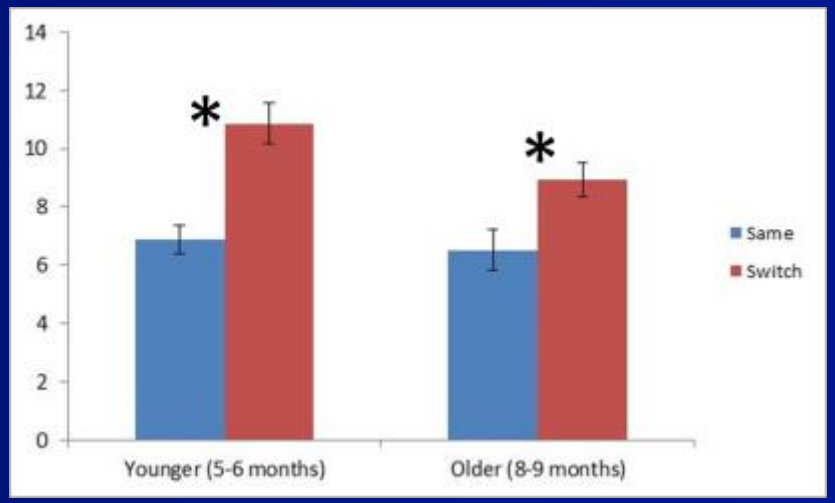
Acoustic analysis	Statements	Questions	t-test
F0 Peak height 1st syll (Hz)	255	255	.16, p = .91
F0 range 1st syll (Hz)	67	66	0.12, p = .9
F0 range 2nd syll (Hz)	-25	192	23.46, p<.001
Final F0 (Hz)	163	380	23.61, p<.001
Duration (ms)	529	765	11.91, p<.001

2. Native discrimination: Exp. 1 statement/yes-no question

- Participants
  - 40 infants (from monolingual homes in the Lisbon area) split into two age groups: 5-6 months, 8-9 months
    - 20 younger (8 female, M = 5 months 29 days, range 5 months 3 days – 6 months 23 days)
    - 20 older (10 females, M = 8 months 12 days, range 7 months 11 days-9 months 29 days)

2. Native discrimination: Exp. 1 statement/yes-no question

- Results: Both age groups display longer looking times to the switch test trials



Infants are able to discriminate utterances that differ only in the prosodic features that cue statements and questions, as early as 5 months, in the presence of segmental variability

ANOVA: within-subject factor trial type (same/switch) and two between-subject factors age group (younger/older) and habituation (statement/question)

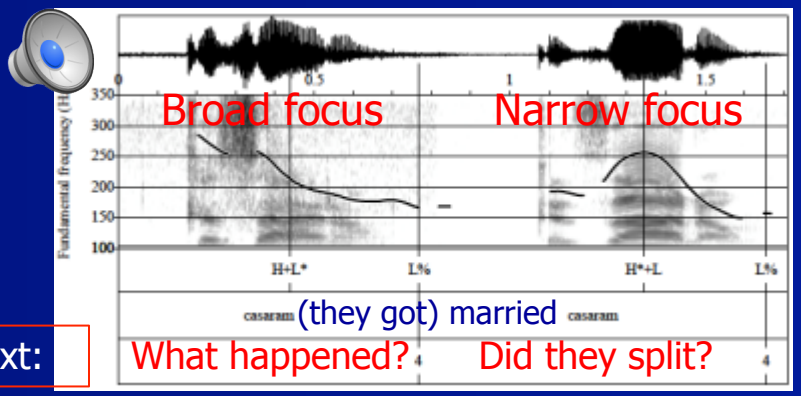
- Significant difference between same and switch test trials ($F(1,36) = 54.18$, $p < .001$, $\eta^2 = .6$)
- No effect of age group ($F(1,36) = 2.13$, $p = .15$, $\eta 2 = .06$)
- No effect of habituation ($F(1,36) = 2.02$, $p = .16$, $\eta^2 = .05$
- No significant interactions (trial type x age group $F(1,36) = 3.29$, $p = .08$, $\eta^2 = .08$; other, $F(1, 36)<1$).

Paired T-tests: significant difference between same and switch trials for younger ($t(19) = 6.1$, $p < .001$, $d = 1.474$) and older ($t(19) = 4.42$, $p < .001$, $d = 0.816$) groups.

2. Native discrimination: Exp. 2

Butler, Vigário & Frota (under revision) Language Learning & Development

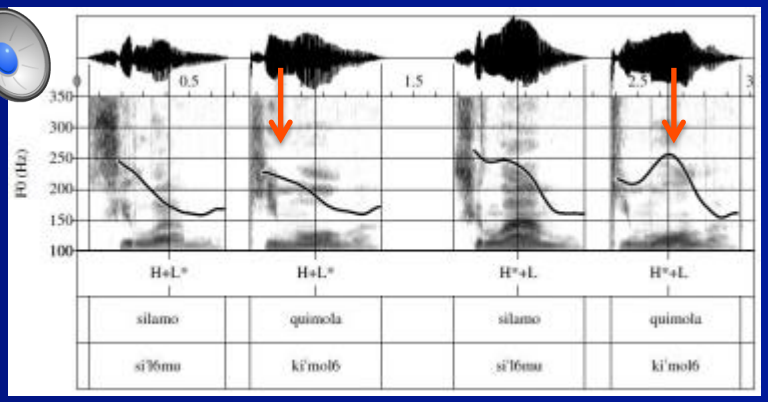
- The broad/narrow focus distinction



  - Broad focus: the whole sentence expresses new information; Narrow focus: a particular element is the relevant part of the utterance (identification, contrast/correction, Krifka 2007, Gussenhoven 2008, Ladd 2008)
  - Main cue pitch timing: broad focus **H+L***L%; narrow focus **H*+L** L%
  - Longer durations in narrow focus; Peak height is optional (Frota 2000, 2002)
  - The prosodic contrast is perceived by adult native speakers (Frota 2012)

2. Native discrimination: Exp. 2 broad/narrow focus

- **Materials:** Segmentally varied one pseudo-word utterances produced by a female native speaker in infant-directed speech



Pitch timing: early/late alignment of the pitch fall

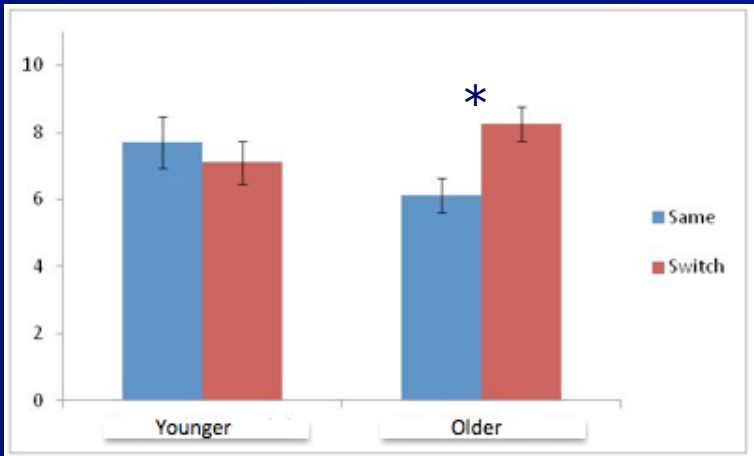
Acoustic analysis	Focus	Neutral	t-test
F0 peak (Hz)	249.79	230.8	7.4, $p < .001$
F0 low (Hz)	160.26	161.53	1.05, $p = .31$
Timing of the fall (ms)	140	- 29	22.12, $p < .001$
Duration pre-tonic (ms)	101	159	6.95, $p < .001$
Duration stressed (ms)	262	254	1.22, $p = .24$
Duration post-tonic (ms)	236	229	1.49, $p = .16$

2. Native discrimination: Exp. 2 broad/narrow focus

- Participants
  - 40 infants (from monolingual homes in the Lisbon area) split into two age groups: 7 months, 12 months
    - 20 younger (10 female, M = 6 months 28 days, range 6 months– 8 months 3 days)
    - 20 older (9 females, M = 12 months 7 days, range 10 months 16 days-14 months 6 days)
- Procedure
  - Same as in Exp. 1
  - If sensitive to the intonational contrast, infants should display longer looking times to the switch (different) trials

2. Native discrimination: Exp. 2 broad/narrow focus

- Results: Only the older infants display longer looking times to the switch test trials



Infants only demonstrate discrimination of utterances that differ solely in the prosodic features that cue broad and narrow focus, by 12 months, in the presence of segmental variability

ANOVA: within-subject factor trial type (same/ switch) and two between-subject factors age group (younger/older) and habituation (broad/ narrow focus)

- No significant effect of trial type ($F(1,36) = 2.34$, $p = .14$, $\eta^2 = .06$)

- No effects of age group or habituation ($F(1,36) < 1$)

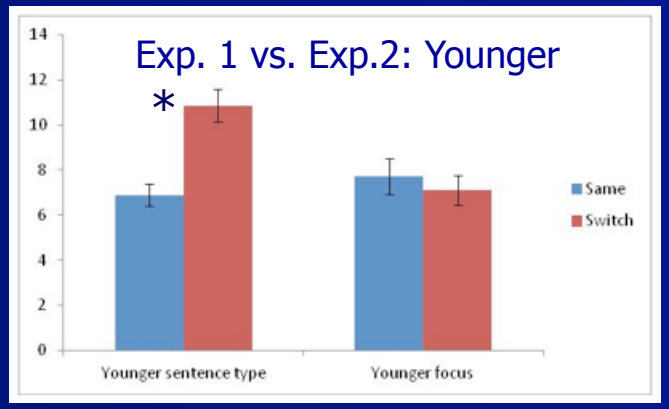
- Significant interaction between trial type and age group ($F(1,36) = 7.82$, $p < .01$, $\eta^2 = .06$.

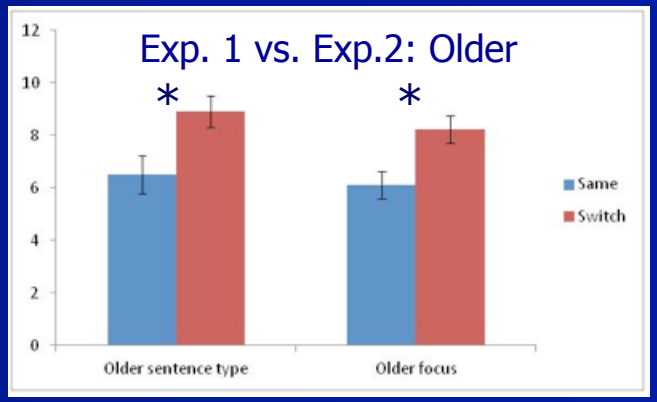
- No other significant interactions (trial type X age group X condition – $F(1,36) = 2.22$, $p = .15$, $\eta^2 = .06$; other, $F(1, 36)<1$).

Paired T-tests: no significant difference between same and switch trials for the younger group ($t(19) = .85$, $p = .41$); but a significant difference for the older group ($t(19) = 3.19$, $p < .01$).

2. Native discrimination of intonational contrasts: Discussion

- Infants learning European Portuguese demonstrate a discrimination ability for the statement/question prosodic contrast as early as 5 months, and for the broad/narrow focus contrast only by 12 months





ANOVA: within-subject factor of trial type (same vs. switch test trial) and two between-subject factors of experiment (decl/int vs. focus) and age group (younger vs. older): significant effect of trial type ($F(1,76) = 36.67$, $p < .001$, $\eta^2 = .33$); significant interaction trial type / experiment ($F(1,76) = 14.14$, $p < .001$, $\eta^2 = .16$); significant interaction trial type / experiment / age group ($F(1,76) = 10.94$, $p < .01$, $\eta^2 = 13$)

2. Native discrimination of intonational contrasts: Discussion

Different discrimination pattern

≠ cues, ≠ developmental paths

- Discrimination with phonetically varied stimuli: ability to perceive the acoustic cues AND to extract and generalize the contrastive patterns (phonological processing)
- Our findings do not support general precocious abilities for pitch-based contrasts. They suggest that the perceptual trajectory of prosodic contrasts depends on the primary cues involved (pitch height & direction vs. pitch timing)
- Highlights the importance of the nature of the particular cues that signal a given prosodic contrast in a given language

3. Non-native discrimination: Exp. 3

Sundara, Molnar & Frota (in progress)

- The statement/yes-no question distinction (Exp.1) perceived by English-learning infants

  European Portuguese:

  – Yes-no questions are string identifical to statements (Mateus et al. 2003)

  – Main cue final pitch: statement: H+L***L%**; question: H+L***LH%**

  English:

  – Yes-no questions and statements have distinct overt syntax structures (i.e., inversion in questions)

  – Final pitch: Statements have a fall (H* **L%**), questions have final high/rising pitch (H* **H%**) (varieties of Northern American English – Pierrehumbert 1980, Fletcher et al. 2005, Ladd 2008)

  Different morphosyntax but Similar pitch cue (fall vs. rise)

  Differences in pitch pattern: nuclear syllable (H+L* vs. H*) and final low rise (LH%) vs. high rise (H%)

3. Non-native discrimination: Exp. 3
English infants, EP statement/yes-no question

- Participants

General early sensitivity to pitch (phonetic salience) predicts early discrimination

  - 20 infants (from English homes in the Los Angeles area): 4 months

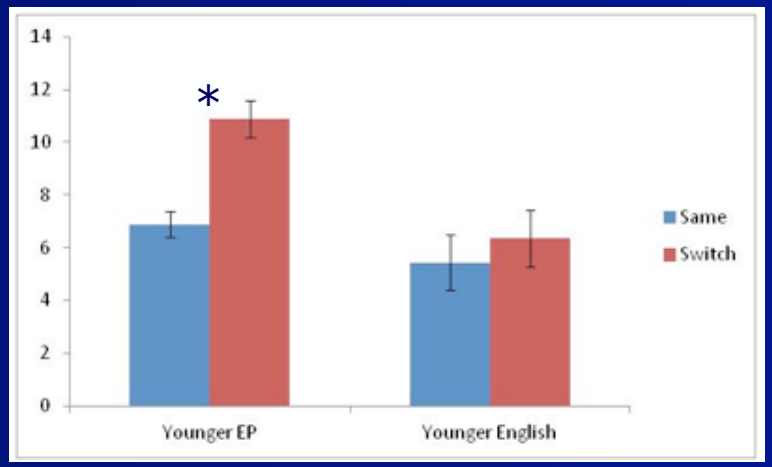
    11 female, M = 4 months 6 days,

    Range 3 months 21 days – 4 months 27 days

    - From the literature on infant perception, no differences in discrimination abilities are expected between 4 and 5-month olds (Sato et al. 2009, for lexical pitch accent [HL / LH]; Yeung et al. 2013 for lexical tone [high-rising/mid level] also Weikum et al. 2007 for visual language discrimination)

3. Non-native discrimination: Exp. 3
English infants, EP statement/yes-no question

- Results: Unlike EP-infants, English-learning infants fail to discriminate the statement/question contrast



English infants do NOT show an early sensitivity to the prosodic features that cue statements and questions in EP, in the presence of segmental variability

English infants: Paired T-test no significant difference between same and switch trials ($T(19) = .91$, $p = .37$

Comparison between Exp1 (native discrimination) and Exp.3:

ANOVA: within-subject factor trial type (same/switch) and two between-subject factors language (EP/English) and habituation (statement/question)

- Significant main effect of trial type ($F(1,36) = 17.21$, $p < .001$, $\eta^2 = .32$)
- Significant main effect of language ($F(1,36) = 14.75$, $p < .001$, $\eta^2 = .29$)
- Significant interaction between trial type and language ($F(1,36) = 6.71$, $p < .05$, $\eta^2 = .16$)
- All other effects and interactions were not significant

3. Non-native discrimination: Exp. 4

Frota, Butler, Lu & Vigário (in progress)

- The distinction between Mandarin Chinese T1+T4 and T1+T2 perceived by EP-learning infants

  The pitch contours of these two tonal sequences are similar to the statement/yes-no question contrast:

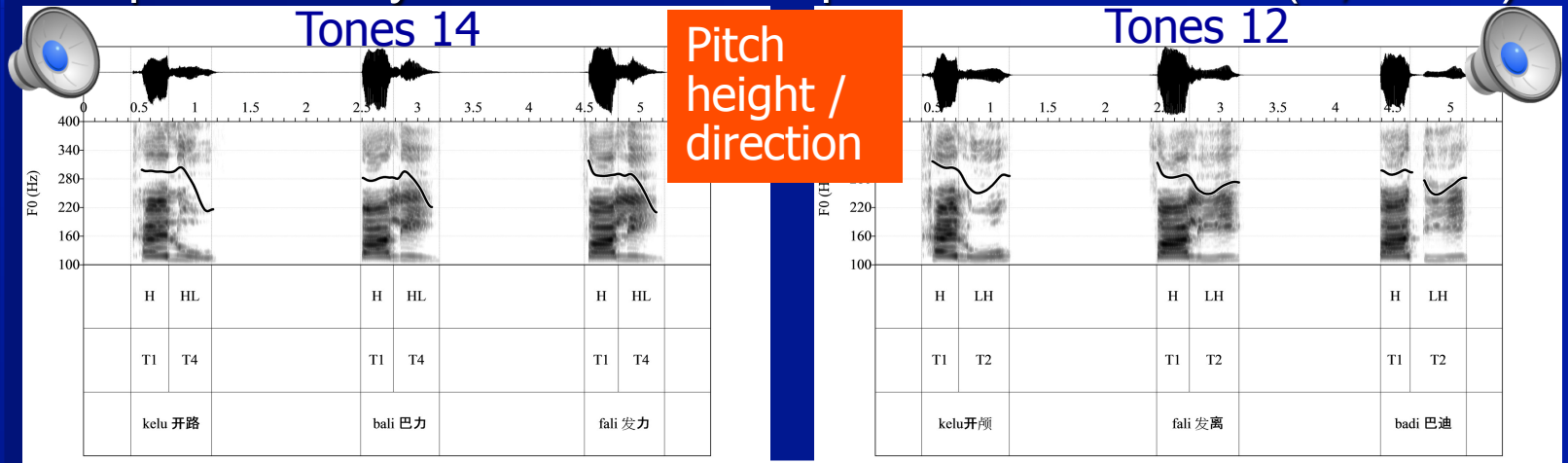
  – Mandarin Tone4 similar to final falling intonation of declaratives
    Mandarin Tone2 similar to final rising intonation of questions
    (other languages, Broselow et al. 1987, Braun and Johnson 2011)
  – Initial high tone+fall / Initial high tone+fall+rise

  Prosodic differences (EP / Mandarin):

  – EP, the contour as a whole is different between statements and questions (≠s in F0 and duration patterns affect both syllables); Mandarin, only the 2nd syllable carries the contrasting cues
  – Different distributions of the fall & rise (e.g., 1st syl: Fall/High)
  – Pitch range ≠ in the 2nd syl is reversed (question wider; 14 wider)

3. Non-native discrimination: Exp. 4
EP infants, Mandarin T1+T4 / T1+T2

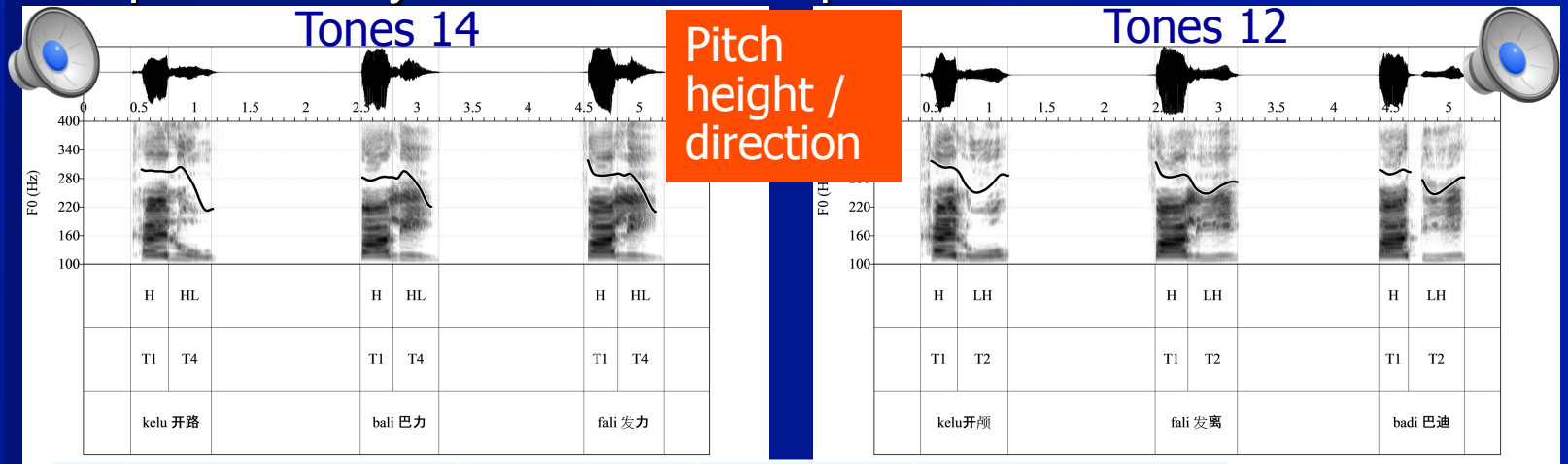
- **Materials:** Segmentally varied bisyllabic (pseudo-)word produced by a female native speaker of Mandarin (C, V=EP)



Acoustic analysis	Tones14	Tones12	t-test	t-test (EP)
F0 Peak height 1st syll (Hz)	306	306	.172, *p* = 87	.16, p = .91
F0 range 1st syll (Hz)	11	10	.74, *p* =. 47	0.12, p = .9
F0 range 2nd syll (Hz)	-103	35	34.94, *p* < .001	23.46, p<.001
Final F0 (Hz)	205	284	28.16, *p* < .001	23.61, p<.001
Duration (ms)	763	801	4.87, *p* < .01	11.91, p<.001

3. Non-native discrimination: Exp. 4
EP infants, Mandarin T1+T4 / T1+T2

- **Materials:** Segmentally varied bisyllabic (pseudo-)word produced by a female native speaker of Mandarin



Acoustic analysis	Tones14/12	Stat/Quest	t-test Man/EP
F0 patterns 1st syll	H / H	HL / HL	-
F0 patterns 2nd syll	HL / HLH	L / LH	-
F0 range 2nd syll (Hz)	103/35	25/192	-
Duration 1st syll (ms)	270/279	310/397	$p = .07$ / $p < .001$
Duration 2nd syll (ms)	493/522	310/437	$p < .01$ / $p < .01$

Differences between the EP and Mandarin prosodic contrasts

3. Non-native discrimination: Exp. 4
EP infants, Mandarin T1+T4 / T1+T2

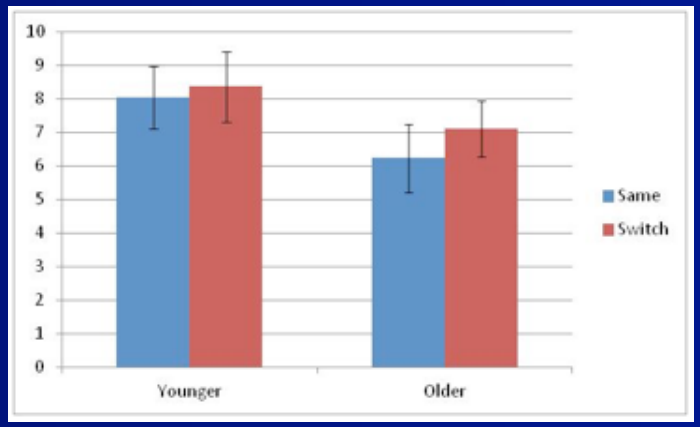
- Participants

General early sensitivity to pitch-based contrasts (phonetic salience) predicts early discrimination

  - 20 infants (from monolingual homes in the Lisbon area) split into two age groups : 5-6 months, 8-9 months (as in Exp.1)
    - 10 younger (4 female, M = 5 months 22 days, range 5 months 2 days – 6 months 19 days)
    - 10 older (5 females, M = 8 months 11 days, range 7 months 15 days-9 months 21 days)

3. Non-native discrimination: Exp. 4
EP infants, Mandarin Tones 14 / 12

- Results: Unlike in the intonation contrast, EP infants fail to discriminate the lexical tone contrast

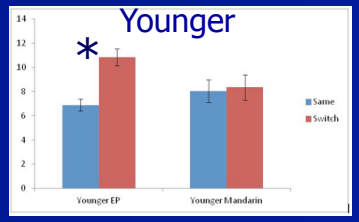


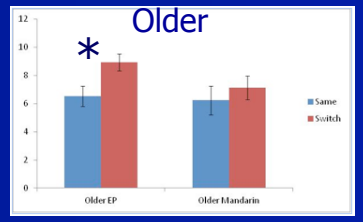
Non-parametric Wilcoxon Signed Ranks Test :

All data: no significant difference between same and switch test trials, z = .68, p = .41.

For the two age groups separately: no significant difference between same and switch test trials for the younger (z = .26, p = .8) or older (z = .15, p = .89) age group.

Comparison between Exp1 (native discrimination) and Exp.4:





EP-learning infants do NOT show an early sensitivity to the prosodic features that cue the Mandarin Tone contrast, in the presence of segmental variability

3. Non-native discrimination of pitch-based contrasts: Discussion

- English 4-month olds fail to discriminate the EP statement/yes-no question contrast
- Similarly, EP infants at 5-6 and 8-9 months fail to discriminate the Mandarin lexical tone contrast
- Exp.3 & Exp.4 > NO early sensitivity to (non-native) pitch-based prosodic contrasts, involving a pitch height & direction difference, in the presence of segmental variability
- Exp.1 > Early sensitivity to a (native) pitch height & direction distinction (at 5-6), that is maintained (at 8-9 months).

3. Non-native discrimination of pitch-based contrasts: Discussion

Late/No discrimination

↓

Early language-specific effects

- Our findings do not support general precocious abilities for pitch-based contrasts, or a general early perceptual advantage for pitch-based contrasts which is independent from the native language
- By contrast, they suggest early language-specific effects, arguing for the importance of the ambient language

4. General Discussion

- Infants' discrimination of native and non-native pitch-based prosodic contrasts in the presence of segmental variability was investigated
  - Does early perception of intonation support precocious discrimination abilities for pitch (as found in previous work), or does the nature of the pitch cues matter?
  - To what extent is early sensitivity to pitch-based contrasts independent from the native language (as suggested in recent work, e.g. Bion et al. 2011, de la Mora et al. 2013)?
- We examined EP-learning infants' perception of two native intonation contrasts:
  - The statement/yes-no question distinction, key cue a pitch direction contrast (falling-low vs. falling/rising)
  - The broad/narrow focus distinction, key cue a pitch timing contrast (early vs. late pitch fall within the syllable)

4. General Discussion

General precocious abilities for pitch NOT supported by early perception of intonation

- We found evidence for a different developmental pattern for the two kinds of intonation contrasts
- This suggests that the perceptual trajectory of prosodic contrasts depends on the primary cues involved (pitch height & direction vs. pitch timing)
  - relating to previous reports on diffs. between infants' perception of lexical pitch, stress and duration contrasts
- Discrimination abilities as a prerequesite for the aquisition of a linguistic distinction cued by prosody > our findings suggest an advantage of certain prosodic cues over others with implications for the acquisition of distinctions marked with different cues

4. General Discussion

General precocious abilities for pitch NOT supported by early perception

- We examined non-native perception of two salient pitch contrasts:
  - EP statement/yes-no question contrast by English-larning infants (falling-low vs. falling/rising)
  - Mandarin T1+T4 vs. T1+T2 by EP-infants (similar to final falling vs. final rising intonation)
- Infants' failed to discriminate > NO early sensitivity to (non-native) pitch-based prosodic contrasts, involving a pitch height & direction difference, in the presence of segmental variability
- This suggests early ambient language effects (Yeung et al. 2013), rather than early general discrimination abilities for pitch

4. General Discussion

- Potential candidates for early ambient language effects:
  - Consistency of the prosodic cues as the sole markers (or not) of a given linguistic distinction (English ≠ EP)
  - Consistency and variability of the prosodic cues in Infant Directed Speech (≠s across languages, English/EP?)
  - Differences between native and non-native overall pitch patterns, beyond the similarities (Eng ≠ EP; Mandarin ≠ EP)
- No general early perceptual advantage for pitch in linguistic stimuli & an early sensitivity to native language input
- Calls for further research across languages

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