

# The perception of boundary tones in infancy

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## ABSTRACT

We investigated English-learning 4-month-olds' ability to discriminate a final rise versus fall in pitch that distinguishes questions from statements in Portuguese and English. Using visual habituation, we showed that English-learning 4-month-olds failed to categorize segmentally varied Portuguese statements vs. questions. They only succeeded when tested with restricted segmental variability in a more sensitive procedure. Finally, we showed that Basque-learning 4-month-olds have no difficulty categorizing Portuguese statements and questions.

Thus, unlike their Portuguese-learning peers, English-learning 4-month-olds are limited in their ability to distinguish Portuguese statements vs. questions. This is not simply because of the use of non-native speech stimuli, as demonstrated by the success of the Basque infants. This implies that infants' perception of boundary tones is already language-specific at 5-months. Additionally, our results provide a way to reconcile previous puzzling findings about English-learning infants' difficulty in categorizing English statements from questions.

**Keywords:** development, intonation, statements, questions.

## 1. INTRODUCTION

Pitch can signal differences in word meaning like consonants and vowels (e.g. tones in Mandarin), or mark prominence and/or edges of prosodic units (e.g., intonation in English, Portuguese). Like consonants and vowels, infants' ability to discriminate lexical tones becomes language-specific with age [9, 16].

We know less about when infants perceive pitch marking of prosodic units. In Portuguese, statements and yes/no questions are segmentally identical but distinguished by a boundary tone – a fall (L%) versus a rise on the final syllable (LH%); and Portuguese 5- and 8-month-olds are able to distinguish them, even in the presence of segmental variability [4].

In English as well, statements and yes/no questions differ in their boundary tones. Like in Portuguese,

statements in English are characterized by a final fall in pitch, whereas yes/no questions involve a final rise [8]. Additionally, English statements and yes/no questions differ in morphosyntax, and consequently, word order.

Despite their precocious sensitivity to prosody [e.g., 7], English-learning infants have difficulty distinguishing English statements and questions based on pitch alone [13, 5]. This may be because boundary tones are only one cue to distinguish English statements from yes/no questions. The extent of variability in pitch in English infant-directed speech [13] is another factor that is likely to hinder English-learning infants' ability to discriminate a final rise from a fall.

We tested English-learning 4-month-olds' ability to distinguish Portuguese statements from questions for two reasons. First, we wanted to account for the previously reported failure of English-learning infants to distinguish English statements from questions. Portuguese statements and questions are segmentally identical and differ only in the boundary tone – a final rise or fall. Testing English-learning infants on Portuguese stimuli thus allowed us to determine if English infants are able to discriminate boundary tones per se when all else is controlled. Second, we wanted to determine whether Portuguese-learning 5-month-olds' ability to categorize boundary tones in the face of segmental variability is a consequence of their language experience. If it is, then English-learning infants, lacking this experience, should fail to discriminate Portuguese statements from questions.

## 2. EXPERIMENT 1: SEGMENTAL VARIABILITY

With a design like that used in [4], in Experiment 1 we investigated English-learning 4-month-olds' ability to distinguish Portuguese bisyllabic statements from questions. The experimental design required infants to abstract away from segmental differences to successfully discriminate boundary tones. Previous cross-linguistic research shows that the presence of irrelevant segmental variability provides a more challenging environment for infants' discrimination of prosodic differences (stress: [12]; tone: [11]).

## 2.1. Procedure

We implemented a fully-infant controlled version of the visual habituation procedure [15] using Habit X [2]. Presentation of auditory stimuli was contingent on infants' looks to a black-and-white checkerboard. The experiment had 4 phases: pre-test, habituation, test, and post-test. In the pre- and post-test trial infants listened to "pok" recorded by a native female English speaker in an infant-directed register. Listening time to these trials were monitored to gauge infants' attention to the task. In the habituation phase, infants were presented with either Portuguese bisyllabic statements or questions (counterbalanced). When listening time to 4 consecutive trials fell below 60% of the listening time to the first 4 trials, the test phase started. The test phase consisted of one familiar trial (same category as habituation) and one novel trial (different category from habituation). Infants' listening times to the familiar and novel trials were compared statistically.

## 2.2. Stimuli

The stimuli were the same as in [4], namely 16 segmentally varied, single-prosodic word utterances consisting of bisyllabic, all sonorant pseudo-words with initial stress (e.g., /malo/, /lemo/, /mela/, /luma/, /lamo/, /rina/). The stimuli were produced by a female native Portuguese speaker in infant-directed register. Different pseudo-words were used for the habituation and test phase.

## 2.3. Subjects

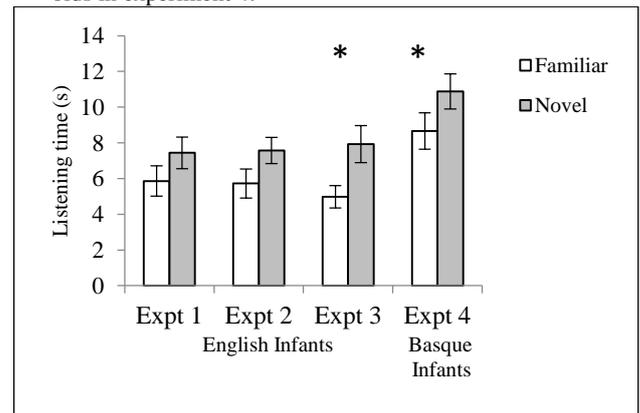
Data from 22 monolingual English-learning 4-month-olds were included in the final analysis (mean age = 127 days; range = 114:148; 12 girls). Five additional infants were tested but excluded because they did not complete testing (3), did not habituate in 25 trials (1), or were learning a tone language (1). All infants were full-term, healthy and had more than 90% exposure to English as per a detailed parental questionnaire [14].

## 2.4. Results & Discussion

An ANOVA with Habituation Condition (statement, question) and Trial-type (familiar, novel) as the independent variables and listening time as the dependent variable was conducted. Neither the main effect of Habituation Condition [ $F(1, 20)=0.003$ ,  $p=0.9$ ] or Trial-type [ $F(1, 20)=3.5$ ,  $p=0.07$ ], nor their interaction [ $F(1, 20)=1.1$ ,  $p=0.3$ ] was significant.

Thus, unlike Portuguese 5-month-olds [4], English-learning infants failed to categorize segmentally varied Portuguese bisyllabic statements vs. questions (Fig. 1). English-learning 4-month-olds' failure to discriminate Portuguese statements from questions when presented with segmental variability implies that the success of their Portuguese peers is likely to be a consequence of their language experience.

**Figure 1:** Average listening time (s) +/- SE to familiar and novel trials for English-learning 4-month-olds tested in experiments 1, 2 and 3, and Basque-learning 4-month-olds in experiment 4.



## 3. EXPERIMENT 2: NO SEGMENTAL VARIABILITY

In Experiment 2, we simplified the task by reducing the segmental variability in the Portuguese stimuli. The procedure was identical to that used in Experiment 1; however, the stimuli were just /lamu/ sequences with a final rise or fall.

### 3.1. Subjects

Another 22 monolingual English-learning 4-month-olds were included in the final analysis (mean age = 127 days; range = 111:153; 11 girls). One additional infant was tested but excluded because she had some exposure to Portuguese.

### 3.2. Results & Discussion

Again, in an ANOVA, neither the main effect of Habituation Condition [ $F(1, 20)=0.19$ ,  $p=0.7$ ] or Trial-type [ $F(1, 20)=3.1$ ,  $p=0.09$ ], nor their interaction [ $F(1, 20)=3.2$ ,  $p=0.09$ ] was significant. Thus, despite limiting the segmental variability of the stimulus set, English-learning infants failed to distinguish the final rise from fall (Fig. 1).

## 4. EXPERIMENT 3: NO SEGMENTAL VARIABILITY & A SENSITIVE PROCEDURE

English-learning 4-month-olds' failure to discriminate /lamu/ sequences with a final rise in

pitch as opposed to a fall is surprising. English- or French-learning 4-month-olds have been previously reported to discriminate the Thai monosyllable /ba/ with a low tone, realized with falling pitch, from /ba/ with a rising tone [10]. What would account for this discrepancy?

An acoustic comparison of the Thai stimuli used in [10] and the Portuguese stimuli used here showed that the Portuguese stimuli were, if anything, more discriminable than the Thai tones. Specifically, the fall of pitch in the Thai and Portuguese stimuli was comparable (27 Hz vs. 25 Hz); but the rise was greater in Portuguese (192 Hz vs. 45 Hz). Another possibility is that it is harder to discriminate pitch rises on bisyllabic stimuli, even when the rise is restricted to just the final syllable, than in monosyllables. Finally, it is possible that the procedure used in [10] was more sensitive than the habituation procedure used in Experiment 2. Experiment 3 was designed to address this possibility.

#### 4.1. Procedure & Stimuli

Infants were again tested on /lamu/ sequences with a final rise or fall. In Experiments 1 and 2, infants were habituated till their looking time declined to 60% of the looking time to the first 4 trials. One way to increase the sensitivity of the visual habituation paradigm is to familiarize infants for a longer duration [6; see also 1]. In Experiment 3, the habituation criterion was more stringent; the test phase started only when the listening time to 4 consecutive trials fell below 50% of the listening time to the first 4 trials. Using a more stringent habituation criterion instead of an absolute increase in habituation time accommodates individual differences in habituation rate as well as differences in initial interest in the task.

#### 4.2. Subjects

Another 22 monolingual English-learning 4-month-olds were included in the final analysis (mean age = 128 days; range = 110:147; 10 girls). Five additional infants were tested but excluded because they did not complete testing (1), did not habituate in 25 trials (1) or had some exposure to a tone language (3).

#### 4.3. Results & Discussion

To confirm that the more stringent habituation criteria resulted in greater amount of habituation, we compared the extent of habituation in Experiment 2 and 3 using a t-test. As expected, infants were habituated to a significantly greater extent in

Experiment 3 (Mean=57%; SE=1) than in Experiment 2 (Mean=53%; SE=1),  $t(42)=2.2$ ,  $p=0.03$ .

Now, in an ANOVA with listening time as a dependent variable, only the main effect of Trial-type [ $F(1, 20)=7.6$ ,  $p=0.01$ ] was significant [Habituation Condition:  $F(1, 20)=0.3$ ,  $p=0.6$ ; Habituation Condition X Trial-type:  $F(1, 20)=2.7$ ,  $p=0.1$ ]. Thus, when tested on just /lamu/ sequences with a more stringent habituation criterion, English-learning 4-month-olds were able to distinguish a final rise and fall in pitch (Fig. 1). Our results extend the findings on tone perception with English-learning infants. As reported in [10] and [16], English-learning 4-month-olds are able to discriminate a falling pitch and a rising pitch even when it is restricted to the final syllable of a bisyllabic word.

### 5. EXPERIMENT 4: BASQUE INFANTS

In Experiment 4, we wanted to rule out the possibility that English-learning 4-month-olds have difficulty categorizing Portuguese statements and questions simply because the Portuguese stimuli were non-native. For this, we tested Basque-learning 4-month-olds on their ability to categorize Portuguese bisyllabic questions and statements.

In Standard Basque, unlike English, yes/no questions and declarative sentences can be segmentally identical, differing only in their intonation [3]. Both yes/no questions as well as declarative sentences in Basque typically end in a fall (L%), but only the former have a high pitch right before the fall (HL%). Additionally, rises in pitch, though not used to mark the differences between declaratives and yes/no questions, are often used to mark stressed syllables within declarative sentences. If the presence of non-native speech alone makes it difficult to categorize Portuguese statements and questions, we expected Standard Basque learning 4-month-olds to fail to discriminate them. The procedure and stimuli were identical to that in Experiment 1 and [4].

#### 5.1. Subjects

Twenty one monolingual Standard Basque-learning 4-month-olds were included in the final analysis (mean age = 130 days; range = 114:134; 12 girls). Three additional infants were tested but excluded because they did not complete testing due to fussiness or crying.

## 5.2. Results & Discussion

In an ANOVA with listening time as a dependent variable, the main effect of Trial-type [ $F(1, 19)=6.7, p=0.02$ ] as well as the main effect of Habituation Condition was significant [ $F(1, 19)=5.2, p=0.03$ ], although there was no significant interaction between them [ $F(1, 19)=.6, p=0.4$ ]. Thus, Basque-learning 4-mo-olds successfully categorized Portuguese statements and questions, like their Portuguese peers (Fig. 1). From these results we can be sure that English-learning 4-month-olds did not fail in Experiment 1 just because we tested them with non-native speech.

## 6. GENERAL DISCUSSION

In 4 experiments we tested infants' ability to distinguish boundary tones, specifically a rise or fall on the final syllable of a two syllable utterance. Boundary tones like these are often used cross-linguistically to mark the edges of prosodic units. By comparing the performance of English- and Basque-learning 4-month-olds tested here with previously published results on infants learning Portuguese we can draw three conclusions.

First, English-learning infants' previously reported difficulty distinguishing English statements and questions [5, 13] likely stems from their limited ability to discriminate boundary tones. Second, Basque-learning infants' success in distinguishing Portuguese statements and questions demonstrates that English-learning infants' difficulty is not simply because they were tested with non-native stimuli. Finally, 5-month-olds, whether they are learning Portuguese, English or Basque, are already language-specific in their perception of boundary tones; in fact, Portuguese and Basque infants distinguished boundary tones even in the presence of segmental variability. This shows that native language experience influences the perception of boundary tones even earlier in development than vowels, consonants or even lexical tone [9, 10, 16]. The aspects of infants' specific language experience that give rise to cross-linguistic differences in developmental patterns, however, need further investigation.

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